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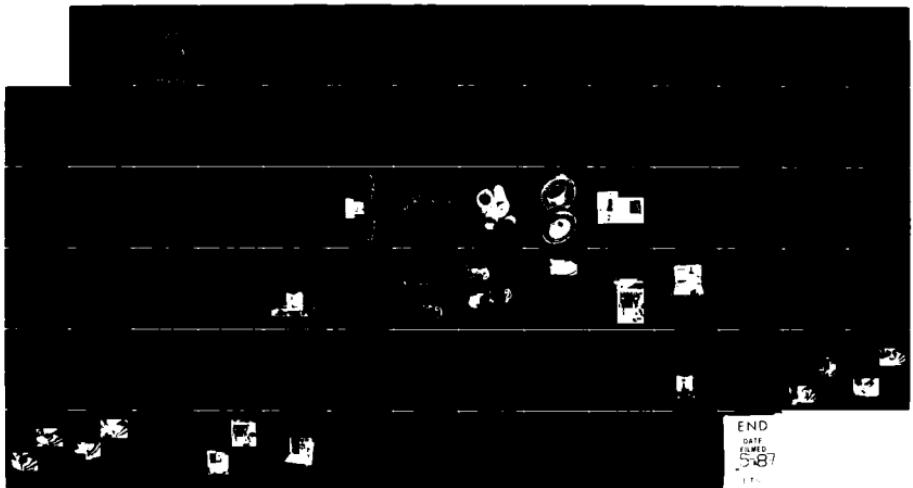
FIELD EVALUATION OF THE SIDESTREAM SENSORS FOR
FILTER/SEPARATORS AND CLAY FILTERS(U) COORDINATING
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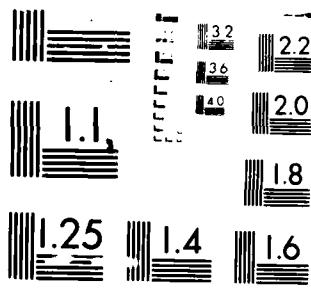
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FIELD EVALUATION OF
THE SIDESTREAM SENSORS FOR
FILTER/SEPARATORS AND
CLAY FILTERS

February 1987

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219 PERIMETER CENTER PARKWAY, ATLANTA, GEORGIA 30346

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FIELD EVALUATION OF THE SIDESTREAM SENSORS
FOR FILTER/SEPARATORS AND CLAY FILTERS

(CRC PROJECT No. CA-47-70)

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Prepared by the
Filter Sidestream Sensor Field Test Panel
of the
CRC Water/Fuel Separation Characteristics Group

February 1987

Aviation Fuel, Lubricant and Equipment Research Committee
of the
Coordinating Research Council, Inc.

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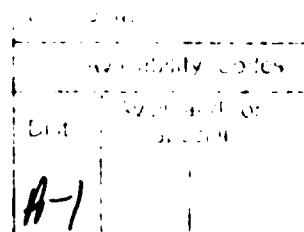


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I. INTRODUCTION

In response to a 1977 survey conducted by the ASTM D 02.1 Subcommittee on Aviation Fuels to assess industry needs in fuel handling, the CRC Water/Fuel Separation Characteristics Group identified six requirements for test methods which CRC should consider:

1. surfactants in fuel;
2. surfactants in the aqueous phase;
3. filter/separator condition;
4. filter/separator life;
5. clay filter condition; and
6. clay filter life.

The Group had received a report from one panel that examined test methods for surfactants in fuel⁽¹⁾ and organized another panel to develop a test for surfactants in water. The last four test needs became the objectives of a panel, established in 1980, to examine the Exxon Filter Sidestream Sensor as CRC research techniques for these purposes. Membership of the Panel and a corresponding working group of the Institute of Petroleum which also evaluated the Sidestream Sensor appear in Appendix A.

II. BACKGROUND

Fuel handling systems for aviation turbine fuel at terminals and airports depend upon multiple filtration units to insure that clean and dry fuel is delivered into aircraft. Most of these units are filter/separators (F/S), which combine the functions of solids filtration and water coalescence and removal in two-stage vessels and are installed on airport mobile vehicles and hydrant servicers, as well as at fixed locations near satellite or storage tanks. A second type of filtration unit employs activated clay elements in a vessel and is installed in a fixed location near a storage tank to remove surfactants from fuel.

Filter/separators are intended to handle millions of gallons of fuel while removing both solid and free water contamination from the fuel. They are designed to accumulate solid contaminants and to coalesce fine water droplets in the first stage elements. Some fuel contaminants may be present only sporadically and only in concentrations of less than parts-per-million, but they may be surface active in nature, meaning that they can partition between the fuel and the aqueous

phases because they have both a polar and a non-polar nature. Surfactant accumulation in a filter-coalescer element interferes with its ability to coalesce an emulsion of water-in-oil by adversely affecting both the fiberglass surfaces and the release mode of droplets from the elements.

One way of detecting this problem is by removing a single coalescer element and testing its coalescing properties by exposing it to a water-in-oil emulsion in a special rig. Such a technique for testing single coalescer elements under recommended conditions was developed by CRC⁽²⁾ and is widely used in the industry. However, the technique has several disadvantages. Element removal requires system shutdown and lost time. Usually the element has to be shipped to another location for evaluation. The tested element usually cannot be reused even if its coalescing properties are still satisfactory. Also, the procedure has never been standardized and the results between units may not be directly comparable.

Clay elements could be tested in a similar fashion, although no published procedure exists. For this purpose, the elements would have to be exposed to test fuel containing a surfactant, and the procedure would have to evaluate the clay's ability to remove the surfactant. Such a procedure would be more cumbersome than the coalescer test and is seldom used. In practice, clay condition is established by checking the fuel upstream and downstream of the clay for surfactant content by a test such as the Microseparometer (ASTM D 3948) or the Minisonicseparometer (ASTM D 3602)⁽³⁾. However, these procedures only evaluate the particular fuel passing through the clay and may not indicate the cumulative effects of other preceding fuels. Other tests, such as membrane color of the effluent fuel, (ASTM D 3830)⁽³⁾ are also used, but furnish only an indirect indication of surfactant presence or clay exhaustion.

All these factors highlight the need for a small on-line device which could monitor the performance of either filter/separators or clay filters⁽⁴⁾.

The need is met by a sidestream test cell developed by Exxon Research and Engineering Company and reported to the Filtration Society⁽⁵⁾ and the SAE⁽⁶⁾. Young described to the SAE⁽⁶⁾ the results of both rig and field tests on both types of Filter Sidestream Sensor (FSS) conducted since 1977.

The verification of FSS test results with single element tests using the CRC procedure seemed convincing to the CRC Water/Fuel Separation Group, and, as a consequence, a panel was created to extend the field trials to other locations in both the United States and Europe. Tests got under way in 1980, but because accumulation of contaminants in handling systems is a long-time process, it was not until 1984 that enough data were obtained to verify the soundness of the FSS concept as a monitoring technique.

III. DESCRIPTION OF THE FILTER SIDESTREAM SENSORS

A. Principles of Sensor Testing

The key to successful monitoring of the condition of elements in an operating filter/separator (or clay) unit is dynamic similarity of the sidestream sensor. Dynamic similarity between sensor and main filter is provided by maintaining geometric construction similarities to assure that fuel flow rates across various filter components are matched. Sidestream operation provides two advantages: a cumulative history of factors similar to the actual filter, and the ability to test the sensor, regardless of whether the main filter is operating or not.

In this report, the sensor across the Filter Separator Unit is called the Filter Sidestream Sensor (FSS), while the sensor across the clay unit is called the Clay Sidestream Sensor (CSS).

The FSS assembly is pictured in Figure 1 and shown mounted across a filter/separator unit in Figure 2. Flow enters the assembly through an inlet probe and is controlled by a valve on the flowmeter. Once set, the flowmeter maintains a proportional flow to the sensor, with variations in main unit flow. Flow is directed through the sensor holder containing the sectioned filter components in a capsule (see Figure 3) and then back to the main line downstream of the main vessel. Differential pressure across the main filter provides the driving force through the sidestream.

Two types of filter coalescer elements are pictured in Figure 4, showing the section which is used to construct the Sidestream Sensor. Flow is inside to outside. Solids filtration is accomplished by the pleated paper, or inner surface. Coalescence of water is initiated by contact of droplets with fibers of paper and fiberglass, and proceeds rapidly outward to the woven sock, where water droplets collect and grow. Each component of the element is cut from one that is identical to the type installed in the vessel and placed in a capsule holder and gasketed to provide an exact duplication of the flow per unit area. In the case of the pleated paper, a proportionally larger flow area is provided in the capsule to compensate for the greater area of paper. Details of construction of an FSS capsule and assembly into the Sensor holder appear in Appendix B.

A sidestream sensor for a clay canister type unit is designed on a similar dynamic similarity principle comparable to the sensor. As pictured in Figure 5, a cross-section of the canister, in the shape of a truncated cone, becomes the design basis for the Clay Sidestream Sensor (CSS). Flow is from the outside to inside. Details of construction of the Clay Holder appear in Appendix C.

The working and testing principles of the Sidestream Sensor are based on concepts which are detailed in the SAE report⁽⁶⁾:

1. Contaminants in flowing fuel accumulate in the test media at the same rate they accumulate in main filter elements if fuel flow rates are properly proportioned.
2. When a holder is removed to be tested, a flow rate of test fuel at 200% of rated flow is applied, in order that the Sensor provides ample warning of main unit deactivation.
3. For an FSS, a surfactant-free reference fuel is tested to detect contaminant pickup from the Sensor. For a CSS, a reference fuel containing a specific surfactant is tested to detect remaining removal efficiency of the clay. Both sensors are tested in a field type Water Separometer, either the D 3602 Minisonic Separometer, or the D 3948 Microseparometer.
4. The proof of validity of the Sidestream Sensor system for predicting filter unit life is provided by Single Element testing and other field evaluations.

B. Filter/Separator Unit Sidestream Sensor (FSS)

Factors which affect coalescence of water from emulsions when fuel containing water-in-oil emulsions is flowed through a fiberglass bed have been described by numerous investigators⁽⁷⁾. The role of additives or contaminants is a crucial factor in the degradation of coalescence efficiency. Young described and proved several of these factors: the presence of solids, the type of water (e.g., sea water is worse than fresh water) and, most importantly, the concentration of water⁽⁶⁾. A dry fuel; i.e., containing no free water, may contain high levels of additives and not affect coalescer efficiency. A fuel containing up to 100 ppm of free water will exhibit a fairly rapid effect on coalescer degradation. However, if the fuel contains larger amounts of water (say 1,000 ppm), the degradation rate is much slower, apparently due to washing effects.

In the field, fuels will vary considerably in water content, depending on temperature variations and the presence of other water separation systems, such as tank settling. An airport fuel survey, conducted by the CRC Filter Charging Group, suggested that fuels in hydrant systems are dry about two-thirds of the time⁽⁸⁾. The rest of the time, fuel is apt to contain low levels of free water, representing the most critical range for coalescer degradation. Rarely will the fuel contain high levels of free water, especially near the aircraft (unless an upset has occurred). Regardless of water level, fuel may contain surfactant contaminants. Although these surfactants can be detected by

a water separation test, such as the ASTM D 2550 procedure or the field counterparts such as D 3602 and D 3948, the weakness of using the test to predict filter performance is apparent, since free water level is really the controlling factor.

The water removal efficiency of filter/separators is normally assessed by testing the effluent fuel for free water, using either the D 3240 Aquaglo or a pass/fail type chemical detector test. In his rig tests, Young used free water levels of 15 to 30 ppm in effluent fuel as the criterion for unacceptable coalescer degradation when introducing at least 50 ppm of free water with fuel⁽⁶⁾. To sense degradation in the FSS, the capsule and holder are installed in a Minisonic Separometer (MSS), or Microseparometer (MSEP), and exposed to an emulsion of 3,000 ppm of water in reference fuel (rated at 98-100 WSIM by the MSS or MSEP) at twice the flow rate normally used in these tests. The turbidity of the last third of effluent from the capsule is measured, as in the standard MSS and MSEP procedure. The capsule and holder are then replaced in the sensor housing and the testing continued. Details of the FSS testing procedure appear in Appendix B.

If the Sensor has accumulated surfactant contaminants, the emulsified water will extract some of them, because of their partial polar nature and lower the MSEP rating of the reference fuel. The reason for adding 3,000 ppm to form the emulsion, instead of 1,000 ppm, used in MSEP testing, is to insure that sufficient water is present to wet the filter components in the capsule and perform an initial extraction. The second test (at 1,000 ppm), specified in the detailed procedure, recognizes that under extremely dry conditions even 3,000 ppm of water may be lost in merely saturating the capsule.

The Panel expressed concern that repeated testing of the FSS could remove enough surfactant to invalidate future ratings of the FSS when it was returned to the operating unit. In his testing Young evaluated two FSS devices installed in parallel, one tested periodically, the other only at the end of the trial period. Both gave the same results. Young also ran repeated tests on a particular FSS with successive readings as follows: 69, 65, 74, 91, 95. It was concluded that it takes more than three successive tests to remove surfactant and restore coalescence activity. These findings lent confidence to the particular FSS testing procedures specified for field trials.

The relationship between FSS ratings obtained by the above procedure and the actual levels of free water in effluent from a full-scale 600 GPM filter/separator was reported to the SAE⁽⁶⁾ and is reproduced as Figure 6. An FSS rating of 85 is equivalent to about 15 ppm of free water in F/S effluent. The strong correlation between tests on the Sidestream Sensor and actual filter performance encouraged the CRC to investigate a wider range of field installations.

C. Clay Unit Sidestream Sensor (CSS)

Once it was recognized, some years ago, that surfactants could be picked up by jet fuel in distribution systems, such as pipelines and tankers, (regardless of how well the refinery removed them), a movement began to install filter units containing activated clay at distribution destinations and at some airports. In fact, the development of the D 3602 Minisonic Separometer and the D 3948 Microseparometer was inspired by the need for a field instrument to test fuel at terminals for surfactants and to monitor the effectiveness of a clay filter.

Clay is an excellent adsorptive medium for polar impurities, such as surfactants. Its efficiency and life depend upon the amount of active surface exposed to flowing fuel. Unless the clay unit happens to be operating on a low WSIM fuel at the time, there is no reliable way that an MSS or Microseparometer test on the effluent can detect whether the clay is reaching the end of its useful life. This is the role of the Clay Sidestream Sensor which is designed, like the main units, to accumulate surfactants at the same rate.

The CSS is tested periodically by removing the Holder and installing it in the MSS or MSEP unit. Testing of the CSS involves a different routine than testing of the FSS. The Holder is exposed to a reference fuel containing Aerosol O.T. per ASTM D 2550 (at a concentration that produces a rating of 40-60 by MSS or MSEP) at 200% of CSS rated flow and the entire effluent is collected. This step is then repeated and the second effluent collected. Both effluent samples are then subjected to a standard MSS or MSEP test for coalescence by forming an emulsion and collecting the uncoalesced emulsion for turbidity measurement. Duplicate tests insure that enough effluent is collected to achieve a proper sample for MSEP rating. Depending upon the remaining effectiveness of the clay in the Holder, the Aerosol O.T. will be removed from the reference fuel and the MSEP rating upgraded from its 40-60 starting level. After testing, the Holder is then returned to the Sensor housing and the CSS remains on test. Details of the CSS testing procedure appear in Appendix C.

The relationship between Clay Sensor ratings obtained this way and the performance of a full-scale 600 ppm clay unit, as reported to the SAE⁽⁶⁾, is reproduced in Figure 7. The large unit was exposed to fuel containing a conductivity additive with surfactant properties. It is evident that at the time the Sensor effluent ratings had dropped to 90 WSIM, the main unit elements were revealing a loss in effectiveness in removing the conductivity additive. The excellence of this correlation between sensor ratings and clay unit performance encouraged the CRC to investigate a wider range of field installations.

IV. TEST PROGRAMS

A. Objective and Scope

The objectives of the Field Test Panel were four-fold:

1. to verify the proposed Sidestream Sensor test procedures;
2. to obtain correlation of sensors with field results;
3. to establish criteria of filter/sePARATOR and clay deactivation; and
4. to validate use of the removable capsule concept.

In selecting test sites for installations, the Panel sought locations which demonstrated relatively short filter life due to non-solid contaminants, which were known to handle fuels containing surfactants, or which were suspected to be problem areas because of other indicators; e.g., black water from filter/sePARATOR sumps, high Membrane Color ratings, doubtful Single Element Test results. The following test locations were utilized in the U.S.:

San Jose, CA terminal	(F/S)
Atlanta, GA International Airport	(F/S & Clay)
New York JFK International Airport	(F/S & Clay)
Chicago O'Hare International Airport	(F/S & Clay)

An Institute of Petroleum Panel in the United Kingdom had adopted similar objectives and expanded the original Exxon field test locations to include the following, each of which involved filter/sePARATOR units only:

Copenhagen, Denmark
Nice, France
Basle, Switzerland
E. Midlands, England
Aberdeen, Scotland
Shannon, Ireland
London, England (Heathrow Airport & Perry Oaks Terminal)

The installation of the FSS at each location generally conformed to the recommended design. Panel members assured that the FSS was installed and calibrated properly and supervised the training of operators to remove the Holder, at intervals, to test it, using the Minisonic Separometer or Microseparometer. Testing intervals of 2-4 weeks were recommended. In the event the elements in the filter/sePARATOR (or clay) units had to be changed, due to pressure drop increase, the operators were instructed to install new Holders.

V. TEST RESULTS AND DATA ANALYSIS

A. Clay Sidestream Sensor (CSS)

Clay sensors were installed at three locations originally, but only the Atlanta and New York (JFK) airports produced suitable test results. At O'Hare (Chicago) Airport, the operator advised the Panel that CSS tests were considered inconclusive because the fuel tested in 1981 was line-flush material used to condition a new system, rather than operational fuel.

1. Atlanta International Airport

Test results from two runs at the Atlanta International Airport installation are summarized in Table I. The initial run started in May 1981, but the CSS was constructed with used clay from the operating filter unit, which had been on-stream for many months. It was the practice to monitor clay unit effectiveness by testing fuel for surfactants, using the D 3948 Microseparometer test. On July 3, the CSS was tested for the first time. Results showed that the clay was spent with a CSS rating of 59. At the same time, MSEP tests disclosed that no increase in rating occurred as fuel flowed through the main unit, confirming that the clay was spent. A second test, with fresh clay, began on August 26, 1981. In the subsequent nine months, four tests of the CSS were made: the ratings of 92 to 100 suggested that the clay was still active. In test period 2-4, Microseparometer tests of fuel disclosed that the clay unit could improve fuel by about 20 MSEP; it was decided to continue the test.

By September 1982, thirteen months after the test began, a CSS test showed the clay to still be effective after 158 million gallons of throughput. At this point, the MSEP tests of fuel showed only small improvement. However, the test was extended until the following April, nineteen months after start, at which point the clay elements were changed due to rust clogging of the supporting screen. At this point, the CSS tests showed that the clay was spent. (The two CSS results for period 2-6 in Table I reflect two different reference fuels used in testing. The first was below the specified range of 40-60 MSS rating as prepared, the second above this range. The results of CSS testing show that clay was incapable of upgrading these reference fuels significantly.)

2. New York (JFK) International Airport

Test results from eight runs at JFK (New York) International Airport are summarized in Table II. The CSS was installed on one (No. 2) of the three clay filter units on December 17, 1981, and tested periodically. The three JFK units handle very large volumes of fuel in batches of 10,000 to 50,000 barrels. A WSIM rating by MSEP was run on almost every incoming batch and occasionally on the output fuel. However, the main criteria for change of clay elements is Membrane Color (MC) (ASTM D 3830), which is run downstream of each clay unit and downstream of the final filter/separators. A Membrane Color rating of 5 on output fuel, a differential pressure of 5 psi, a low MSEP rating of incoming fuel or high free water readings are signals for possible change of clay elements. These criteria were also used to judge how often to take CSS readings. The improvement in MSEP or Membrane Color ratings were not normally used to judge clay effectiveness.

The first four test periods lasted from three to eight weeks. Test period No. 1 ended because of poor Membrane Color readings in effluent fuel. Test No. 2 ended when high free water was observed, while Test No. 3 exhibited poor MSEP improvement. In each case, the CSS readings signalled that the clay was becoming spent. Test period No. 4 ended with a poor CSS reading. Test period No. 5 lasted three months and was only changed due to the high throughput achieved; the MSEP ratings showed the clay to be active, and the CSS readings confirmed this. Test periods 6 and 7 each lasted three weeks and terminated due to poor Membrane Color ratings. In both cases, the CSS readings signalled that clay was becoming spent. In the last test period (No. 8), the four-week test terminated when MSEP ratings (poor improvement) showed that the clay was becoming spent. The CSS reading was questionable, due to malfunction of the Microseparometer tester which had not been properly calibrated.

In summary, during the ten test periods conducted at Atlanta and New York airports, clay deactivations occurred nine times, and in each case the CSS ratings signalled deactivation by exhibiting MSEP values below 85.

B. Filter/Separator Sidestream Sensor (FSS)

Test results from two of four United States locations are summarized in Table III, and from eight European locations in Table IV. The test run at Chicago (O'Hare) Airport involved a mismatch between the filter used to prepare the FSS and the type

used in the operating unit. In the case of the JFK Airport installation, every one of the eight test runs terminated prematurely because solids caused pressure drop buildup before any surfactant effects could be observed. Hence, only two U.S. and eight European locations of the FSS produced useful data.

1. U.S. Field Trials of the FSS

(a) San Jose Airport

The first test period, at San Jose Airport, covered a three-month period in 1981. The FSS tested at two-week intervals showed no degradation, even though WSIM ratings on fuel at these intervals gave values in the 70's. In April, and again in May, a single element test showed zero water in the effluent, but a reduction in droplet size, which the operator considered the proper criterion for element change. Based on the time for water drops to emerge in the Single Element Test (SET), it was apparent that the element was very dry. It was known that fuel being handled at San Jose was undersaturated with water most of the time. As a consequence, both the FSS and the filter elements exhibited essentially no pickup of surfactant contaminants, even though fuel tests for WSIM indicated that they were present.

The second test at San Jose started in June 1981, and continued until February 1982, at which point pressure drop buildup forced a change in elements. During this nine-month period, the FSS showed consistently high ratings, while single element tests usually continued to show zero water in the effluent. As in the first test, the long time for water droplets to emerge in the Single Element Test suggested a very dry element and system. It is interesting to note that at two test intervals, when effluent water from the Single Element Test reached 1-5 ppm, the time period for droplet emergence dropped from 100 to about 40 seconds. These results suggested that fuel through the system was not always completely dry, and that a very small amount of water was sometimes trapped in the element.

(b) Atlanta International Airport

The FSS test program started in March 1981 by assembling a test capsule from a used filter element. The filter/sePARATOR was downstream of a clay filtration unit, where the CSS was on test. In July, tests of FSS gave ratings of 100, but by March 1982, a year

after the test period began, and after 155 million gallons of fuel throughput, the FSS ratings were at 80. This first indication of coalescer degradation coincided in time with the first receipts of fuel from a new pipeline. (The MSEP rating of this fuel was 73, but the clay unit improved it to 95 before exposure to the filter/sePARATOR and the FSS.) In April, the elements were changed. A Single Element Test showed good coalescing properties at that time; the FSS rating of 93 suggested that very little surfactant contamination had accumulated.

In summary, although eleven properly run field trials of the FSS were conducted at U.S. airports, only three were not prejudiced by the presence of particulates, which terminated the trial prematurely. In each of the three cases, the FSS predicted or confirmed the satisfactory performance of the filter elements from the full-scale system when these were tested in a Single Element Tester. The only field installations where surfactant contamination was found that actually affected filter performance were in Europe.

2. Institute of Petroleum Field Trials of FSS

Field trials at the eight European locations were much more successful in producing useful data relating FSS to filter/sePARATOR performance. At the time the program of the Institute of Petroleum was initiated in early 1981, ten Exxon locations had installed the FSS. The eight locations shown in Table IV include some of the original test sites, plus others managed by other companies. About 20 test runs, representing time periods from two to forty-nine months, are summarized in this table.

Test locations of Company A were at London (Heathrow Airport and Perry Oaks Terminal), Shannon Airport (Ireland), and Kastrup Airport (Copenhagen). Tests at Heathrow had lasted almost four years, by mid-1981, and showed high FSS ratings and good activity by elements in a test. Shannon Airport was another contaminant-free location which produced similar results. Tests at Perry Oaks had started in 1983, after a series of filter changes, due to pressure drop buildup. In April, the FSS rating suggested deactivation, but by June, the FSS ratings improved to 93. The element removed at this point showed spots on the outer sock, but was still active in a Single Element Test. A second test trial at Perry Oaks, in 1983, showed similar high FSS ratings and good element activity in tests after four months.

The first test trial at Copenhagen, in 1981, which lasted ten months, suggested a serious contamination problem, confirmed by an FSS rating of 27 and a Single Element Test showing poor coalescence. Steps were taken to correct the poor quality of fuel to the airport, and a new trial began in 1983. FSS ratings declined to a low of 41 in June, and elements were changed. In the next trial, FSS ratings again dropped rapidly. Elements from both trials were rated active in Single Element Tests, provoking an investigation of testing procedures. It was found that the capsules in the Sensor Holder were not sealed properly. As a result, when an emulsion was applied during the Microseparometer test, bypassing took place, and a low reading resulted. When the loose fitting of the capsule was corrected, the FSS ratings rose to 95, confirming the activity of elements when tested.

Test locations of Company B were at Nice Airport (France) and at Basle Airport (Switzerland). FSS tests at Nice started in February 1983. In July, an element was removed for Single Element Tests and rated fair in coalescence. At this point, the FSS rating was 93. By January 1984, FSS ratings at Nice had dropped to 75, but a re-test in England several weeks later gave a 99 result. Another element removed from the unit showed good coalescence in the Single Element Test. There was suspicion that the testing procedure for the FSS in the field was at fault, or that bypassing of emulsified fuel took place within the capsule, but this suspicion could not be confirmed.

Tests at Basle also started in February 1983. FSS ratings were 100 until August when a single element was removed and found in testing to be completely deactivated. A second and third element were rechecked by Single Element Tests at different locations, and shown to give good coalescence performance. The poor performance of only one of the six elements in the filter/sePARATOR remains unexplained. It was noted that the filter/sePARATOR unit at Basle operated at an unusually high pressure drop. The deactivated coalescer was found to contain gummy deposits and stained paper, which could not be removed by solvent. Two more test trials were conducted at Basle, in 1983 and 1984, and in each case high FSS ratings were measured and matched by good element ratings in the Single Element Test.

Test locations of Company C were at East Midlands Airport (England) and at Aberdeen Airport (Scotland). Tests at East Midlands began in February 1982. After four months, FSS ratings continued to show readings of 100, and elements removed for Single Element Tests were in excellent condition. The first test period at Aberdeen Airport began in

a Single Element Test on an element showed poor coalescing efficiency. The I.P. Panel noted that fuels at both East Midlands and Aberdeen locations contained sulfonates, but, whereas fuel was dry at the former test site, it was known to be wet at the latter test site.

Six test trial periods at Aberdeen Airport followed the initial run. Three test periods, between August 1982 and January 1983, showed good agreement between FSS ratings and Single Element Tests on elements, although free water transmission appeared to be increasing. In the fourth test period, the Single Element Test failed while the FSS rating showed 100. Sulfonate tests of water bottoms from the Single Element Test unit revealed a rising trend suggesting that surfactants were present in the Aberdeen fuel. After the fifth test period, it was discovered that the valves were turned off and no flow was taking place through the FSS. This period of no flow may have affected the final FSS result after the sixth test period.

VI. RELATING FIELD PERFORMANCE TO SENSOR ANALYSIS

A. Clay Sidestream Sensor

As expected, the clay sidestream sensor overcame shortcomings of monitoring clay filter condition by testing fuel samples by Microseparometer or by Minisonic Separometer. Both inlet and outlet fuel must be tested simultaneously and the differences examined to determine whether a clay filter is still active. The first test period at Atlanta illustrates the point: a downstream result of 95 would have predicted good clay condition, but the same rating on upstream fuel would leave unanswered the question of clay condition. However, the zero difference in these readings suggested that clay was spent, and the CSS results confirmed this. At the other extreme, Atlanta Test 2-4 illustrates that fresh clay can increase WSIM ratings by about 20 points. In this test period, the high CSS rating also confirmed the activity of the clay.

At JFK Airport, the CSS was tested on 27 occasions during the course of the eight test periods shown in Table II. On each of these occasions, MSEP ratings of fuel in and out or Membrane Color ratings were made at the same time. These ratings make it possible to estimate when surfactants were either present or relatively absent. The 32 test trials represented by both Tables I and II have been scored for agreement between CSS rating and clay element condition for both surfactant-containing and surfactant-free fuels as follows:

Surfactants Present:	<u>Number of Test Trials</u>		
	<u>Yes</u>	<u>No</u>	<u>Total</u>
<u>Clay Element Condition</u>			
Active	11	14	25
Spent	3	4	7
<u>CSS Rating/Clay Condition</u>			
In Agreement	14	16	30
Not in Agreement	-	2	2
	—	—	—
Total	14	18	32

Based on this score sheet, the CSS appears to correlate with clay element field performance as monitored by either MSEP improvement or Membrane Color of effluent fuel over 90 percent of the time. When surfactants were present, agreement was 100 percent. A similar excellent correspondence of CSS rating and clay element performance was noted by Young⁽⁶⁾ who reported three test trials at one field location.

B. Filter Sidestream Sensor

When designed and installed as a filter/separator, the FSS proved its advantages over the frequently used criterion of free water in effluent fuel from the filter/separator. Free water checks did not indicate the need for change-out in any of the cases where both FSS and SET tests showed elements to be deactivated. This was simply due to the fact that the system contained no free water at the time. (Finding free water downstream of a filter/separator could represent equipment failure due to a coalescer rupture and give no warning.) Instead, FSS results were compared to Single Element Tests, which are considered indicative of coalescer condition and further usefulness. Here, the interpretation of results from non-standardized Single Element Test procedures becomes crucial because these tests differ from place to place and do not always follow the CRC procedure.

One example of a problematical Single Element Test result is the first test period at Basle (Table IV). The element removed from the unit was tested by Company C and failed in water coalescence. The Single Element Test procedure at Company C's laboratory employed test fuel containing 0.75 ppm of a conductivity additive rather than clay treated fuel - the test fluid recommended by CRC. Aside from the differing Single Element Test procedure, the Basle unit exhibited high pressure drop, and the first element tested that failed coalescence was found to contain resin

deposits, carboneous chips, and a heavy stain. This element showed a pressure drop of 30 psi in the Single Element Test, and was obviously different from elements two and three, which were still active in Single Element Tests. It seems reasonable to discount the SET tests of the first element as a consequence.

Failure of the FSS at Aberdeen to detect the onset of poor coalescence in the elements tested in the Company C rig is difficult to explain, especially since the sulfonate tests of water bottoms from the Single Element Test unit showed a rising trend, suggesting that surfactants were indeed present in the Aberdeen fuel and test element. The failure of the FSS could be explained if the fuel were dry, thus permitting sulfonates to pass through without affecting the FSS. This does not seem likely, however, since the test element showed evidence of sulfonate pickup in the water drains.

Considering the twenty-four valid field test trials discussed in this report and summarized in Tables III and IV, it is possible to score the agreement between the FSS Ratings and Single Element Test (SET) results for both surfactant-containing and surfactant-free fuels as follows:

Surfactants Present:	<u>Number of Test Trials</u>		
	<u>Yes</u>	<u>No</u>	<u>Total</u>
<u>Coalescer Element Condition</u>			
Active (SET Good)	5	15	20
Spent (SET Poor)	3	1	4
<u>FSS Rating/Element Condition</u>			
In Agreement	7	14	21
Not in Agreement	1(SET pr)	1(SET pr)	
		1(FSS pr)	3
<u>Total Test Trials</u>	<u>8</u>	<u>16</u>	<u>24</u>

Thus, 21 of 24 field trials (almost 90 percent) showed good agreement between FSS rating and coalescer efficiency as measured by the Single Element Test procedure regardless of whether surfactants were present. However, if only the four trials are considered where testing showed the element to be disarmed, the FSS correctly predicted this result on two occasions, or 50 percent of the time (if the August 1983 test on the Basle element is discounted because of the unusual contamination detected by

high pressure drop, the FSS prediction average is two out of three or 67 percent). A similar good correspondence between FSS ratings and Single Element Tests on used elements was reported by Young⁽⁶⁾ on five field trials at two locations. At one location, two trials showed that surfactants were present and revealed deactivated elements; the FSS Rating was below 85 in one case and below 90 in the other. At the second location, surfactants were absent and correlation was 100 percent.

C. Overall Assessment

Maintaining the integrity of ground filtration systems for removing water and particulate from jet fuel has always been difficult. It is common practice to change filter elements on the basis of either elapsed time or volume throughput, but this practice tends to be expensive in terms of both labor and material costs. Filters plugged with particulate give their warning by increased pressure drop, but filters disarmed by surfactants give no warning. Removing elements to test for water coalescence or surfactant removal efficiency is expensive and not widely practiced. A Sidestream Sensor provides a simple means to monitor the on-stream condition of elements so that change-out is performed only when necessary. The Sensor concept has advantages over alternative testing schemes, therefore, in terms of both economics and operability. The question which the field evaluation answers in this report is how useful and reliable the Sidestream Sensor is as a monitoring device.

The primary objective of any monitor is always to perform correctly in predicting the condition of field elements. If the Sensor errs, does it "fail safe" or "fail unsafe"? A safe failure predicts the unit to be disarmed when it actually is still active. An unsafe failure is more serious because it predicts the unit to be active when it is really disarmed. In particular, how reliable is the Sensor when surfactants are present in the fuel since this class of contaminants is the most difficult to detect.

Of the 32 cases examined for clay units, the CSS predicted incorrectly on only two occasions when the field unit was still able to deliver fuel with Membrane Colors of 4 or better; there were no "unsafe failures". Of the 14 test trials when surfactants were present, the CSS agreement with field performance was 100 percent.

Of the 24 cases examined for filter/separator units, the FSS failed safe in one trial and failed unsafe in two trials. Of the eight test trials when surfactants were present, FSS agreement with Single Element Tests was 87 percent. Four of these Single Element Tests in Europe suggested the presence of surfactants but only three cases unequivocally involved exposure of the Sidestream Sensor to surfactants. In two of these three cases, the FSS did correctly predict deactivation of the element.

Judging the overall accuracy of the Sensor is difficult because of the limited number of failures of actual field units and the relatively few locations where surfactants were present. Of the 60 sensor tests reported here and in Reference 6, one-third involved surfactants and only ten clay elements and six coalescer element failures occurred. The Sensor pinpointed fourteen of these failures. The fact that surfactants were present in the minority of field trials testifies to the overall high quality of jet fuel. At the same time this situation makes it difficult to draw firm conclusions about the reliability of the Sensor testing concept for predicting filter performance. A larger data base would have been desirable.

VII. CONCLUSIONS

1. Microseparometer tests of the Filter Sidestream Sensor correctly predicted the coalescing efficiency of filter elements installed at U.S. and European airports in about 90 percent of the trial periods; in three cases when the element was disarmed the Sensor predicted only two correctly.
2. Surfactants were present in only one-third of the test trials, but the FSS predicted coalescer performance in seven of eight element tests. Because the actual number of coalescer failures was so limited, it was difficult to judge the true prediction effectiveness of the Sensor.
3. One definition of filter coalescer failure is a free water level of 15 ppm in the effluent from a Single Element Test. A MSEP reading of 85 or lower by the Microseparometer FSS test procedure was found to correspond to such coalescer failures.
4. Microseparometer tests of the Clay Sidestream Sensor properly predicted the remaining effectiveness of clay filters for surfactant removal.
5. Surfactant removal failure of clay elements is judged by monitoring the WSIM rating of fuel both in and out of an operating unit; if WSIM rating is not improved or if the effluent rating falls below 95, deactivation is indicated, a condition predicted by a Microseparometer Test of the Clay Sidestream Sensor at a rating of 85 or below. Membrane Color removal by clay elements is also related to deactivation of the clay but to a lesser extent than WSIM improvement.

6. The success of the Sensor requires that the contents of the test capsule be identical with the components of the filter coalescer element or the clay canister. Capsule construction must also match the flow patterns of fuel in an actual element.
7. In confirmation of theory and the rig data which supported the FSS development, field trials indicate that a low level of free water in fuel is an essential factor in the disarming of filter-coalescer elements.
8. The ASTM D3948 Microseparometer or the D3602 Minisonic Separometer are suitable field instruments for testing the FSS or CSS when operated in the special flow rate mode required.

VIII. RECOMMENDATIONS

1. The Research Technique of the Clay Sidestream Sensor for judging the effectiveness and life of clay elements should be referred to ASTM as a basis for a Standard Practice on Testing Clay Sidestream Sensor units.
2. The general concept of monitoring a sidestream flow to predict the effectiveness and life of filter coalescer elements was vindicated by the field test program, but the relatively few cases of coalescer failures which occurred suggested the need for more data. Accordingly, it is recommended that additional field trials of the Filter Sidestream Sensor be conducted, especially in systems that contain surfactants in fuel.

REFERENCES

REFERENCES

1. Coordinating Research Council, Inc., "Evaluation of Fuel Test Methods for Predicting the Performance of Filter/Separators and Clay Filters," CRC Report No. 470, June 1974.
2. Coordinating Research Council, Inc., "Research Technique for Evaluating New and Used Coalescer and Separator Elements of Aviation Jet Fuel Filter/Separators," CRC Report No. 474, December 1974.
3. Annual Book of ASTM Standards, Vol. 05.03.
4. ASTM Survey of Aviation Turbine Fuel Handling Practices (Minutes of D02.J.01 Task Force), May 1977.
5. Young, D.A. and Patoir, H. A., "Control of Jet Fuel Filter/Separator Performance - Filtration and Separation," Sept./Oct. 1979.
6. Young, D. A., "A New Technique to Evaluate Performance of Jet Fuel Filtration Equipment," SAE Paper No. 800771, May 1980.
7. Hazlett, R. N., "Factors in the Coalescence of Water in Fuel," Naval Research Laboratory Report No. 6669, February 1986.
8. Coordinating Research Council, Inc., "A Survey of Electrical Conductivity and Charging Tendency Characteristics of Aircraft Turbine Fuels," April 1975.

T A B L E S
A N D
F I G U R E S

TABLE I

TEST RESULTS - CLAY SIDESTREAM SENSOR TEST LOCATION: ATLANTA AIRPORT

Test No.	Period No.	Cum. Thruput M Gal.	Fuel WSIM (MSEP) In Out	System Tests			CSS TESTS			Remarks
				Δ P at Rated Flow	Clay Change	MSS of Test #1	MSS of Test #2	MSS of Test #2	MSS of Test #2	
1-1	7-03-81	185	95 95	11.0	No	59	66	66	66	CSS constructed with used clay from unit.
2-1	8-26-81	0	- -	-	Yes	94	96	96	96	CSS made with fresh clay.
2-2	11-10-81	31.0	- -	5	No	99.5	99	99	99	
2-3	3-10-82	79.0	73 -	6.5	No	98.5	90	90	90	First fuel receipts from new pipeline
2-4	4-08-81	90.6	75 96	6.5	No	92	96	96	96	CSS reinstalled on 04/19.
2-5	9-24-82	158.2	92 94	No	100	100	100	100	100	
2-6	4-12-83	196.0	- -	Yes	42/90*	-	-	-	-	Clay elements clogged with rust

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* Test results on two different reference fuels.

M = Millions

TABLE II
TEST RESULTS OF CLAY SIDESTREAM SENSORS
TEST LOCATION: JFK INTERNATIONAL AIRPORT

Test No.	Period No.	Date	SYSTEM TESTS ON FUEL				CSS TESTS			
			Cumul. Thruput		WSIM (MSEP)		MP Color		MSS of Test #1	
			M Gal	Min	In	Out	Clay	F/S	Test #1	Test #2
1-1		12-17-81	0		85-95	-	B-1	B-1	100	98
1-2		12-22-81	6.3		80	92	B-2	B-2	97	98
1-3		12-28	9.5		100	-	B-6	B-4	100	100
1-4		1-06-82	17.9						59	85
2-1		1-06-82	0		100	-	B-1	B-1	100	99
2-2		1-13-82	5.3		89-99	-	B-4	B-4	96	96
2-3		1-20	12.0		80	85	B-4	B-4	90	91
2-4		1-30	20.2		75	94	B-3	B-2	100	100
2-5		2-11	29.9		81	99	B-3	B-2	93	97
2-6		2-18	36.4		96	-	B-2	B-4	96	96
2-7		3-09	52.8		-		B-3	B-4	75	80
3-1		3-09	0				-	B-1	100	100
3-2		3-30	18.5		97-99	-	B-2	B-1	90	98
3-3		4-08	26.7		82	89	B-4	B-3	94	83
3-4		4-20	38.6		79	82	B-2	B-2	97	81

-26-

M = Millions
F/S = Filter/Separator

Clay changed #2 unit due to high
free H₂O after #2 unit

Clay changed due to poor MSSP
improvement

TABLE II (Cont'd)

TEST RESULTS OF CLAY SIDESTREAM SENSORS
 TEST LOCATION: JFK INTERNATIONAL AIRPORT

Test No.	Period No.	Cumul. Thruput M Gal	WSIM (MSEP) In Out	SYSTEM TESTS ON FUEL		CSS TESTS		Remarks
				MP Color	After Clay	MSS of Test #1	MSS of Test #2	
4-1	4-20	0	96	-	B-2	100	100	Fresh clay
4-2	5-6	14.4	100	-	B-4	99	100	Fresh clay
4-3	5-24	31.9	94-98	-	B-3	35	96	Clay changed due to poor CSS
5-1	5-24	0	85	95	B-2	100	100	Fresh clay
5-2	6-28	35.1	78	97	B-0	98	99	
5-3	7-12	49.9	97	-	B-3	99	99	
5-4	7-19	56.7	97	-	B-3	100	100	
5-5	7-23	63.0	98	-	B-4	97	98	
5-6	7-30	71.4	94-96	-	B-3	96	98	
5-1	8-17	92.3	81	98	B-2	99	100	Clay changed due to high throughput
6-1	8-17	0	85	96	-	B-3	100	Fresh clay
6-2	9-21	29.3	94-95	-	B-6	82	98	Clay changed due to low MC
7-1	9-22	0	93-96	-	B-2	100	100	Fresh clay
7-2	10-13	21.4	95-100	-	B-6	76	100	Clay changed due to low MC
8-1	10-14	0	91-100	-	B-3	100	100	Fresh clay
8-2	11-12	28.3	85	93	B-2	Off Scale	98	Clay changed due to poor MSEp improvement

M = Millions
 F/S = Filter/Separator

TABLE III
TEST RESULTS OF FILTER/SEPARATOR SIDESTREAM SENSORS
(U.S. Test Locations)

Date	Throughput M gal	Fuel W/SIM (MSP) Into F/S Out Of F/S	FSS Rating*			Single Element Test Results ppm H ₂ O	Remarks				
			3000 ppm	1000 ppm	Time to 1st Drop						
<u>SAN JOSE TERMINAL</u>											
<u>Test 1</u>											
2-25-81	0			100/100							
3-17-81	.695	12	56	100/100	0	.03"					
4-24-81	2.0	12	82	100/100	0	.015-.125					
5-28-81	3.3	14	100/100	0			Changeout on droplet size				
<u>Test 2</u>											
6-01-81	0			100							
8-28-81	4.3	18	99/99	100/100	0	.015-.0625	130				
2-03-81	11.1	43	99/100	99/100	5	.015-.125	40				
1-21-81	11.7	90	96/99	98/100		.015-.125	65				
2-17-81	14.8		99/100	99/100		.015-.125	119				
<u>ATLANTA INTERNATIONAL A/P</u>											
<u>Test 1</u>											
7-30-81	66.0	92.5	100/100	100/100			FSS made from used element				
3-10-82	155.2	95	80/92	80/90			Fuel from new pipeline				
4-08-82	167.0	96	93/98	98/100	<15	Good Rating	Changeout on throughput				

* Immediate/one-minute reading

M = Millions

F/S = Filter/Separator

TABLE IV
TEST RESULTS OF FSS IN FILTER/SEPARATOR INSTALLATIONS
 (European Test Locations)

Test No.	Location	Date of Testing	Duration, Months	FSS ITST			Single Element Test Results ppm H ₂ O	Rating	S/SET Agreement	Remarks
				MS	Rating	Test				
Company A										
1	Heathrow A/P	7-81	45	100	Very Good		Very Good	Good	Yes	
1	Perry Oaks Vera.	6-83	2.5	93	Good		Good	Very Good	Yes	Spots on test element
2	"	10-83	4.3	99	Very Good		2.5	Very Good	Yes	
1	Shannon A/P	7-83	49	100	Very Good		Very Good	Very Good	Yes	
1	Copenhagen	3-81	10	27	Very Poor		60+	Very Poor	Yes	
2	"	6-83	36	41	Very Poor		5	Good		Capsule bypassing - Test invalid
3	"	9-83	2.7	67	Very Poor		5	Good		Capsule bypassing - Test invalid
4	"	11-83	2.7	90	Good		5	Good	Yes	
Company B										
1	Nice A/P	7-83	5.6	93	Fair		10-15	Fair	Yes	
2	"	1-84	11.8	75	Poor		5	Good	No	
1	Basle A/P	8-83	6	100	Very Good		150	Very Poor	No	
1-2	"	9-83	6.5	100	Very Good		9	Good	Yes	
1-3	"	8-83	6	100	Very Good		-	Good	Yes	
Company C										
1	E. Midlands A/P	2-82	5.8	88	Very Good		0	Very Good	Yes	
1	Aberdeen A/P	2-82	6	81	Poor		25	Poor	Yes	
2-1	"	9-82	1.5	99	Very Good		0	Very Good	Yes	
2-2	"	11-82	3	100	Very Good		5-10	Good	Yes	
2-3	"	1-83	5	95	Good		10-15	Fair	No	
2-4	"	2-83	6.3	100	Very Good		30	Poor	No	
2-5	"	3-83	7.3	-	No Flow		-	Good	Yes	
2-6	"	5-83	9.0	100			10	Good		

FIGURE 1
EXXON RESEARCH AND ENGINEERING COMPANY
FILTER SIDESTREAM SENSOR

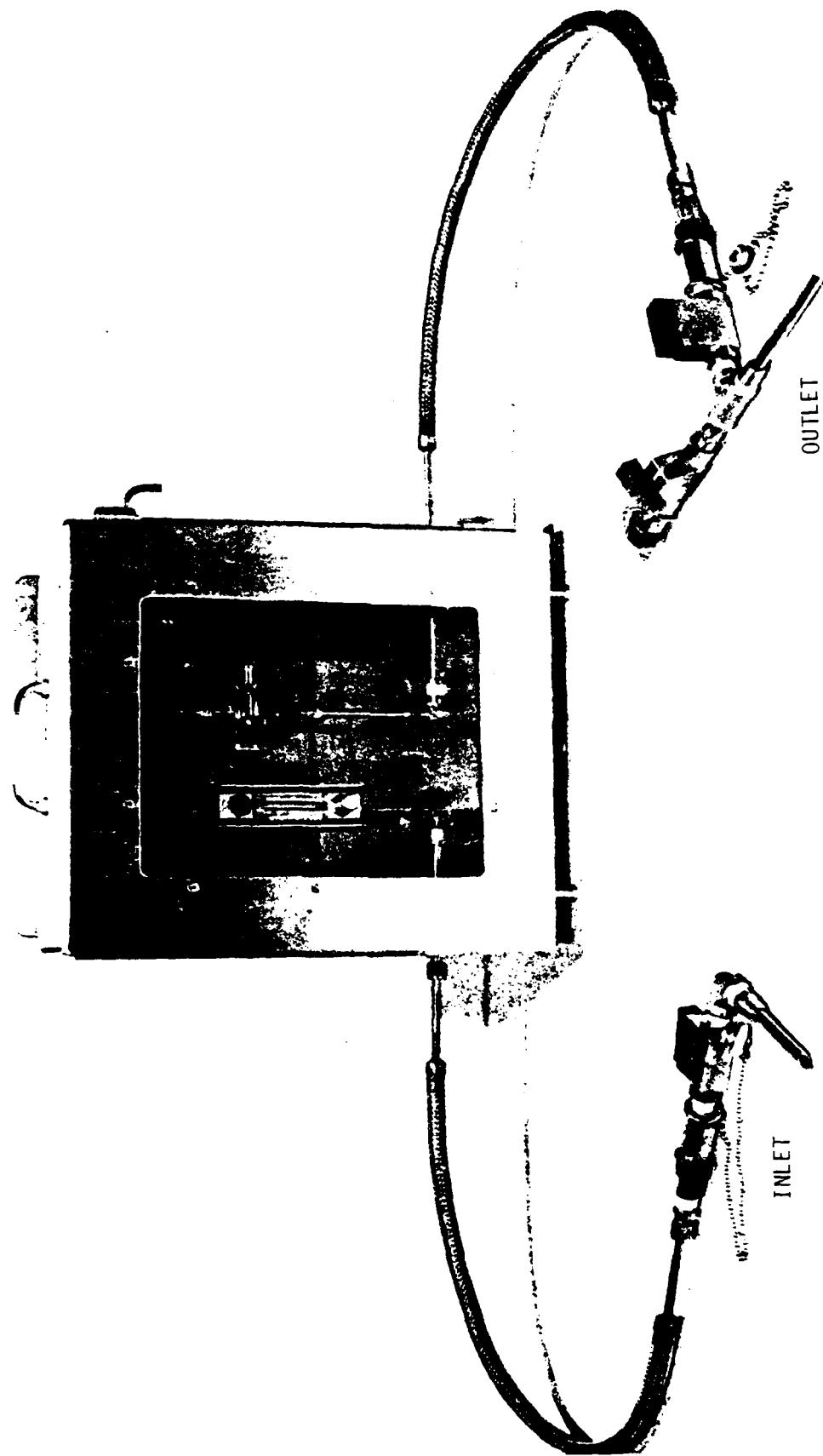


FIGURE 2

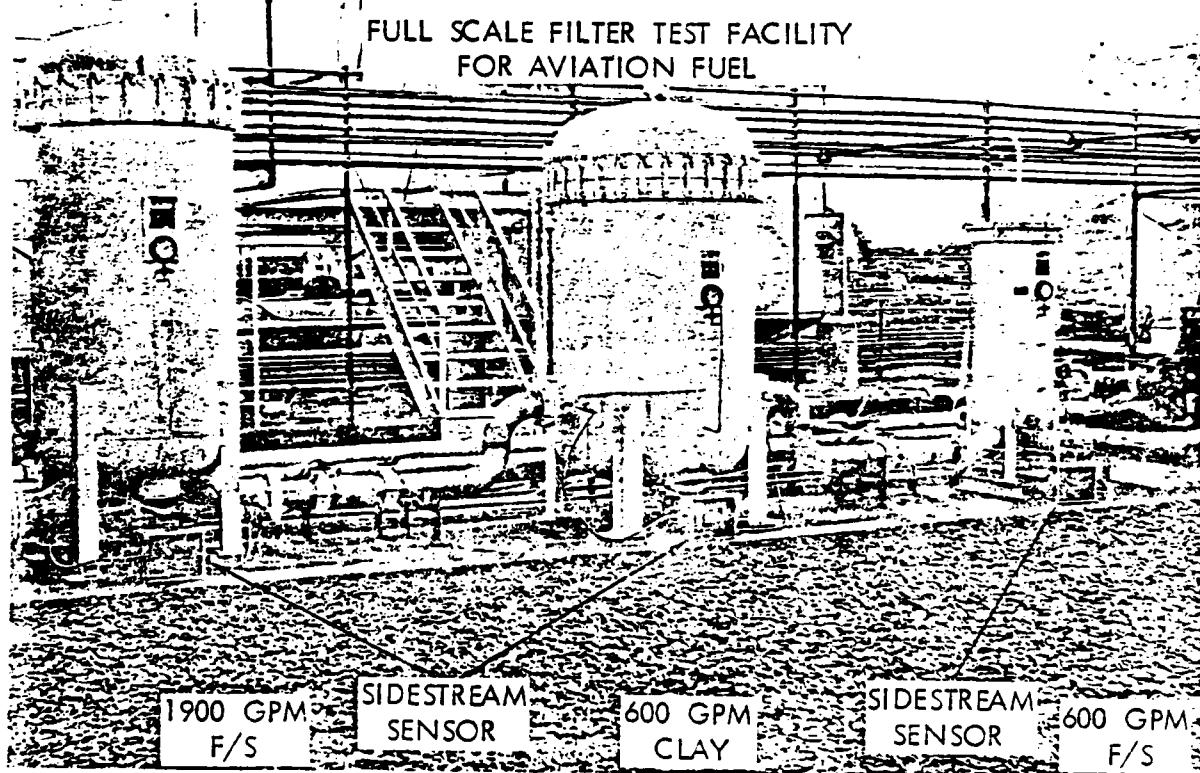


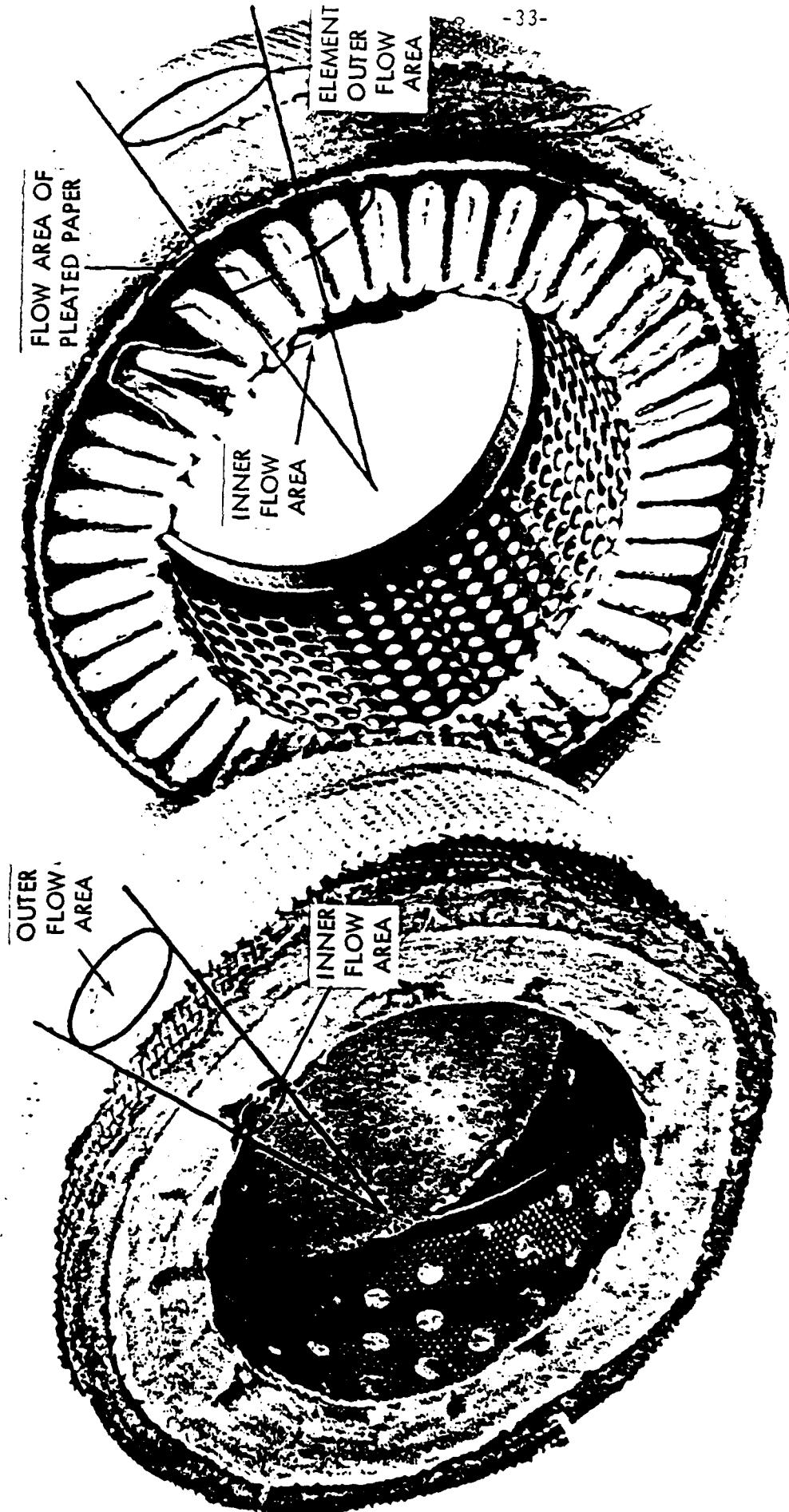
FIGURE 3



FSS HOLDER WITH SECTIONED COALESCER COMPONENTS

FIGURE 4

SECTIONED FILTER COALESCER ELEMENTS



NOTE: The truncated cylinder represents the volume of element that is inserted into the test capsule of the filter Sidestream Sensor.

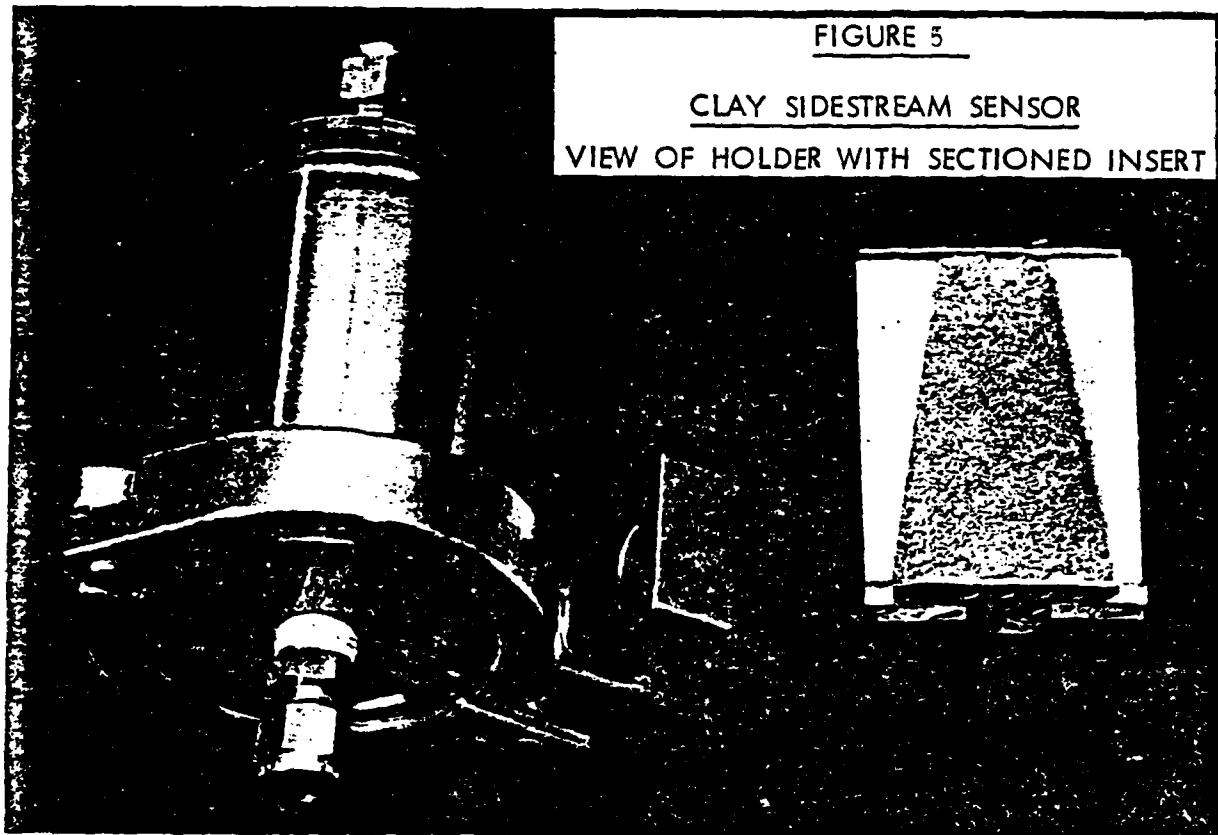


FIGURE 6

FILTER SIDESTREAM SENSOR RATING CORRELATES WITH MAIN ELEMENT WATER LEVEL⁽⁶⁾

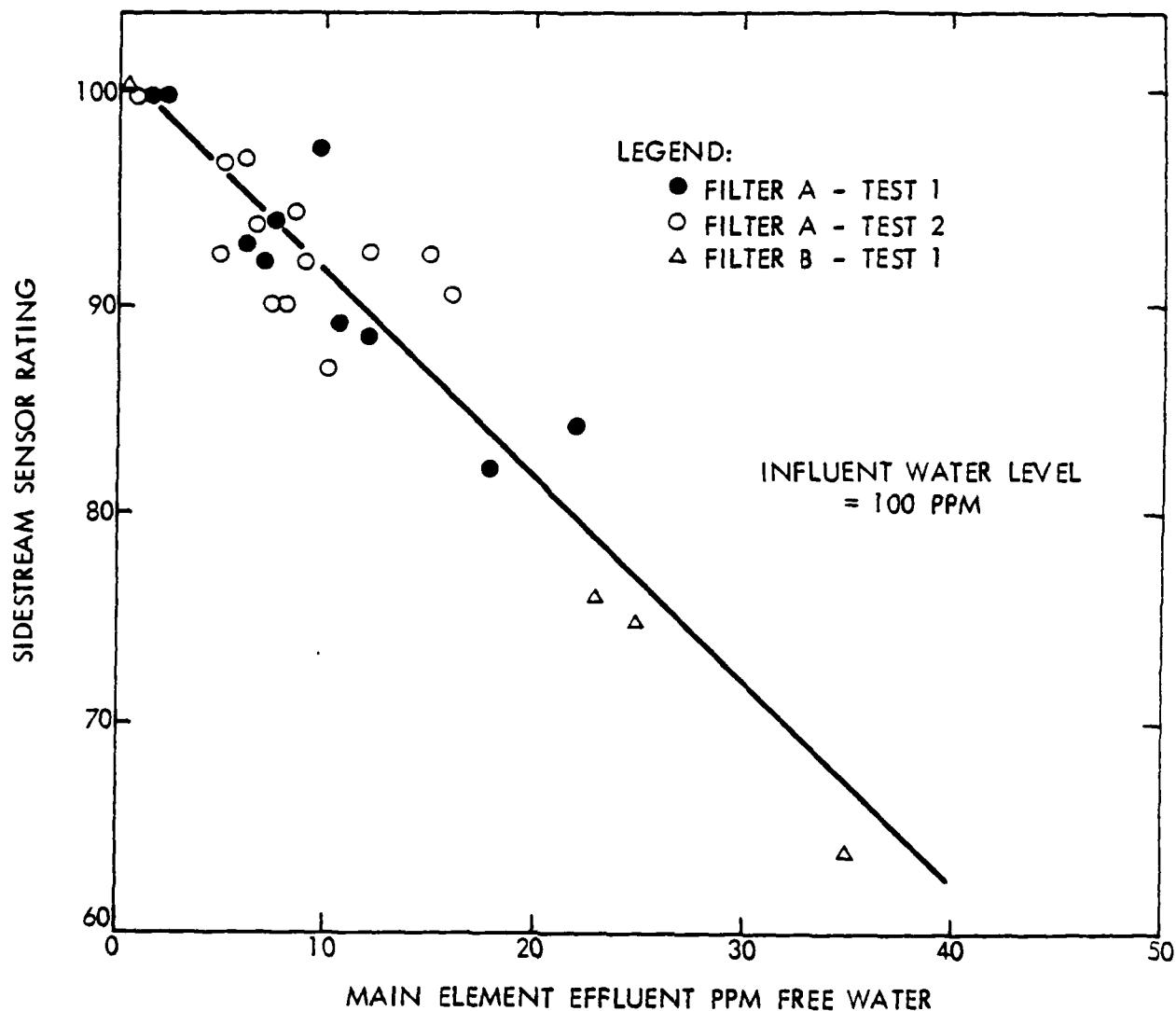
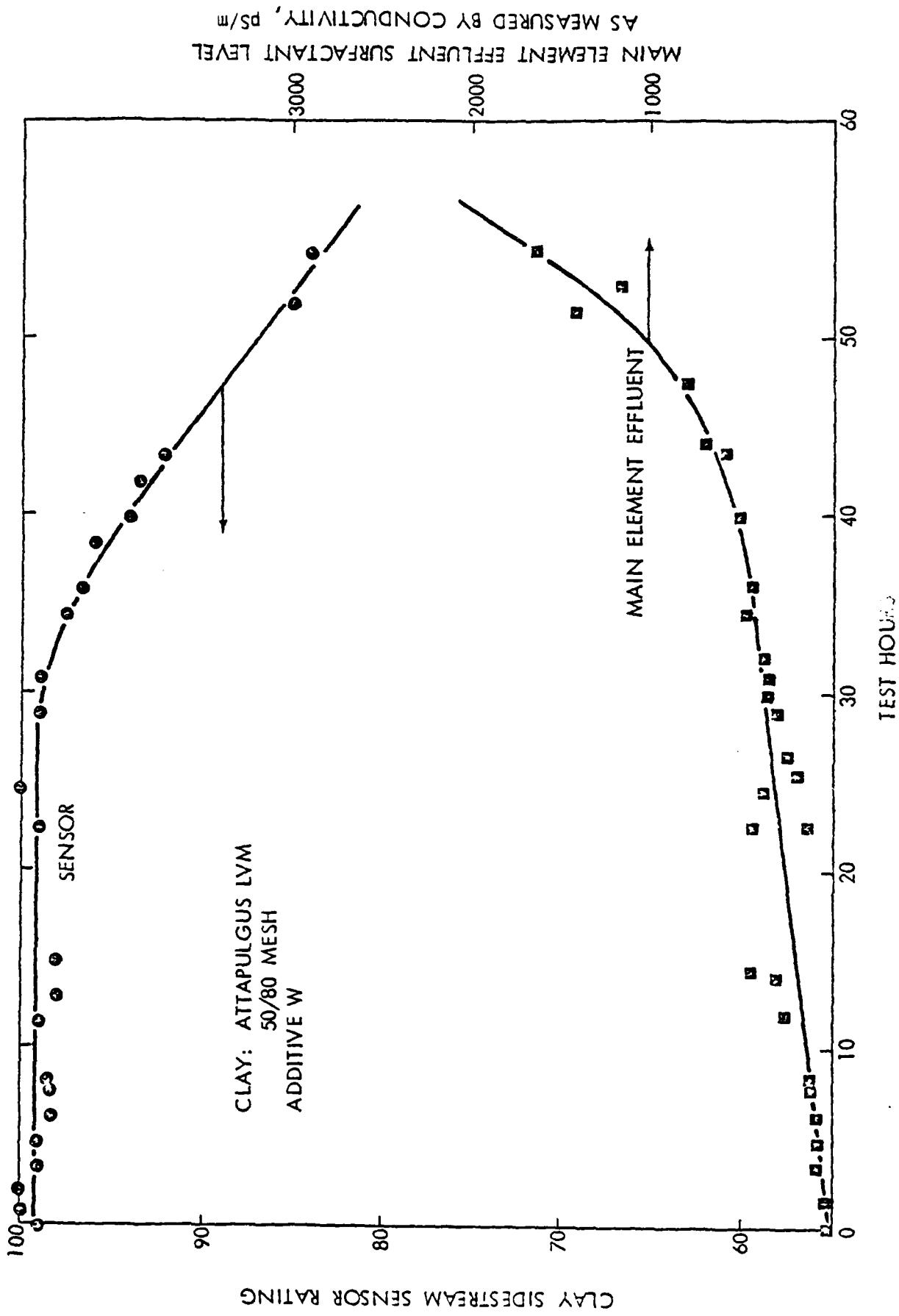


FIGURE 1
CLAY SIDE STREAM SENSOR RATING FOLLOWS DEGRADATION OF MAIN CLAY EFFLUENT (6)



APPENDIX A

GROUP AND PANEL MEMBERSHIPS

CRC FILTER SIDESTREAM SENSOR FIELD TEST PANEL

Name	Affiliation
P. T. Barlow	Shell Research Ltd.
J. J. Bowlds	Trans World Airlines
S. E. Casper	United Airlines
H. M. Gammon	Gammon Technical Products
P. W. Kirklin	Mobil Research & Development
R. K. Russell	Chevron, USA
J. G. Scheltens	Lockheed Air Terminal
K. H. Strauss	Consultant
M. H. Trimble	Delta Air Lines
D. A. Young*	Exxon Research & Engineering Co.

I. P. FILTRATION WORKING GROUP

N. J. Preston, Leader	Esso Europe
K. Algar	British Petroleum Trading
G. J. Datschefski	Esso Petroleum
G. S. German	British Petroleum Trading
G. D. Newbury	Shell International
M. Willars	Shell Research

REPORT SUB-PANEL

W. G. Dukek	Exxon Research & Engineering Co.
H. M. Gammon	Gammon Technical Products
K. H. Strauss	Consultant
D. A. Young*	Exxon Research & Engineering Co.

* Deceased

APPENDIX B

OPERATING MANUAL:

FILTER SIDESTREAM SENSOR
FOR
FILTER/SEPARATORS

FILTER SIDESTREAM SENSOR

FOR

FILTER SEPARATORS

I. INTRODUCTION

Filter/separators are widely used in aviation fuel handling systems to remove (1) dirt and particulates and (2) water from the fuel. In general, as dirt accumulation in the filter elements increases, the resistance to flow increases and the differential pressure across the elements rises. It continues to rise until a maximum allowable limit is reached, at which point the coalescer elements are replaced. If differential pressure is not limiting, then elements are normally changed after a specified length of time.

While the change in pressure differential across the coalescer elements provides a good warning of the extent of useful life with regard to solids build-up, there is no similar warning when the elements lose their ability to coalesce free water from the fuel. Loss of coalescence becomes obvious only after an excessive amount of water is found in the fuel downstream of the filter/separator. That may be too late to prevent a potential hazard to the aircraft.

Because of the lack of early detection of coalescer deactivation, there has been a long standing need in the aircraft fueling industry for a testing technique to assess the on-going performance and remaining useful life of coalescers. Recently, a Filter Sidestream Sensor has been developed to do this task. Extensive testing has demonstrated that the Filter Sidestream Sensor technique is a very effective tool in measuring and monitoring the on-going performance of coalescer elements.

II. WHAT IT IS

The Filter Sidestream Sensor is an external device used to measure or monitor water coalescence capability. It is housed in a small rectangular Cabinet containing the following major components:

- o A Capsule consisting of a pre-packaged filter coalescer section which is of the same material and layer construction as the coalescer elements contained in the filter/separator vessel which is being monitored. Capsules are available for a wide variety of brands and grades of coalescer elements.
- o A Holder into which the Capsule is fitted.
- o A Flow Meter for setting fuel flow rate through the Capsule, proportional to the flow rate through the filter separator vessel.

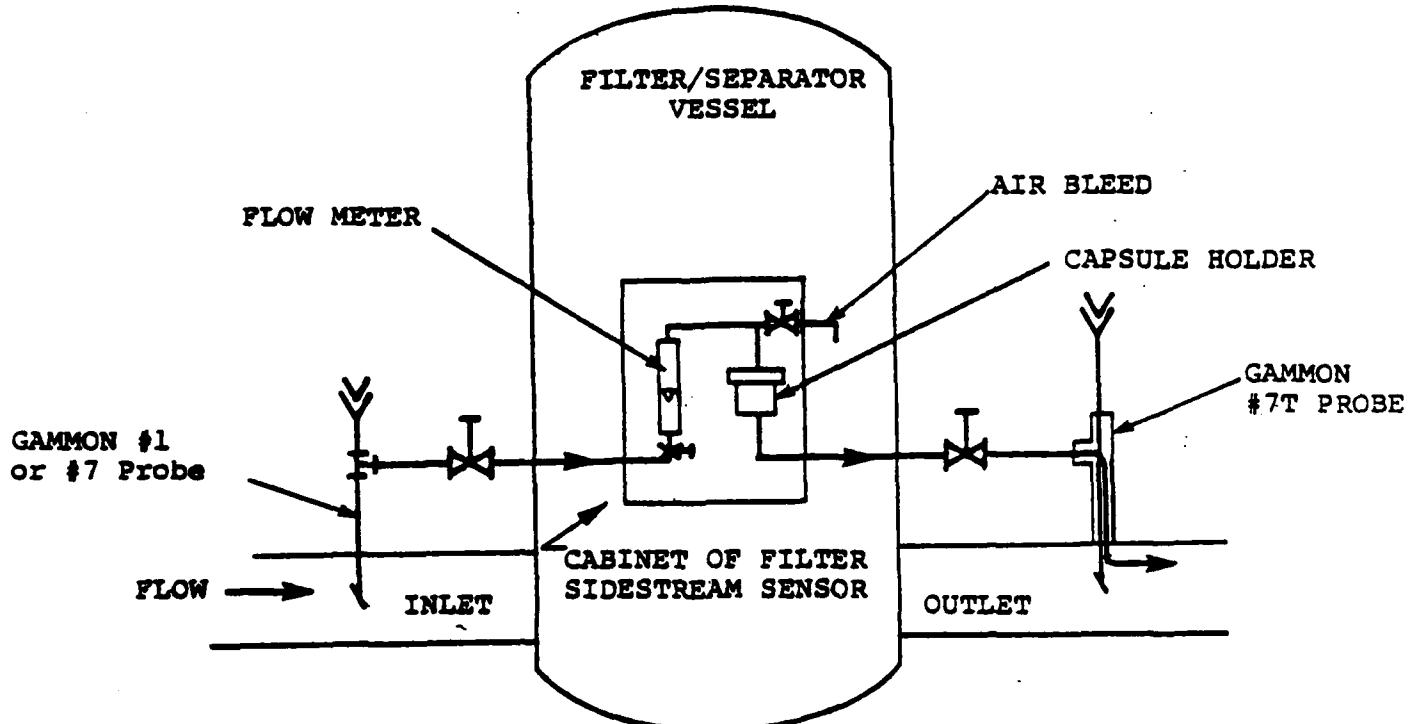
Supplementary equipment, which may already be installed, is also necessary:

- o Sampling probes for insertion into the inlet and outlet connections of the filter/separator.
- o Tubing, valves and fittings for connecting the Cabinet to the sampling probes. For reasons of safety, all connections should be of metal.

A schematic of the Filter Sidestream Sensor attached to the filter/separator vessel, together with sampling tubing and probes, is shown in Figure 1:

FIGURE 1

SCHEMATIC OF FILTER SIDESTREAM SENSOR INSTALLED ON FILTER/SEPARATOR



NOTE: Probes should extend to near the center of the pipe.

III. WHAT IT DOES

The Filter Sidestream Sensor provides a realistic measure of current filter/separator performance in terms of its ability to coalesce free water from the fuel. As such, it is intended to replace the existing requirement for changing coalescer elements on a specified time basis. Along with other existing operating controls, it helps in monitoring the on-going performance and determining the remaining useful life of coalescer elements.

IV. HOW IT WORKS

Fuel enters the Filter Sidestream Sensor through the inlet probe at a rate proportional to the flow rate entering the filter/separator vessel. The Sensor inlet flow rate is set by the valve on the Flow Meter. Once the rate is set, the Flow Meter automatically maintains flow to the Capsule in exact proportion to any flow variations in the filter/separator vessel.

The Filter Sidestream Sensor works on the principle of dynamic flow similarity between the Capsule and the coalescer elements in the filter/separator. Each component of the coalescer element is gasketed in the Capsule to duplicate flow per unit area. The Capsule is changed at the same time as the coalescer elements in the vessel. Thus, as designed and operated, the Capsule is exposed to the same cumulative effects of fuel contaminants as are the coalescers in the filter/separator vessel.

Periodically, the Capsule Holder is removed from the Cabinet and tested for its ability to coalesce free water from the fuel. Details of the test procedure are provided under the section entitled "Operating Procedures".

V. WHERE AND HOW INSTALLED

The Cabinet should be firmly attached with brackets to the filter/separator vessel body or at a convenient location close to the vessel so that the sampling lines are as short as possible. It should be mounted at eye level to permit easy reading of the Flow Meter. For maximum accuracy, the Flow Meter must be mounted in a vertical position (with the aid of a plumb).

The sampling probes, if not already installed, must be extended through the pipe wall, well into the main line flow. Refer to Figure 1 which provides a schematic of the installation.

Fuel sampling tubing should be of metal, preferably stainless steel, and installed so that it will not be damaged during maintenance operations.

A shut-off valve should be installed in both the inlet and the outlet lines between the Filter Sidestream Sensor and the sampling probes - to shut off fuel during periodic removal and testing of the Capsule Holder. These valves should be installed as part of the sampling probe assembly.

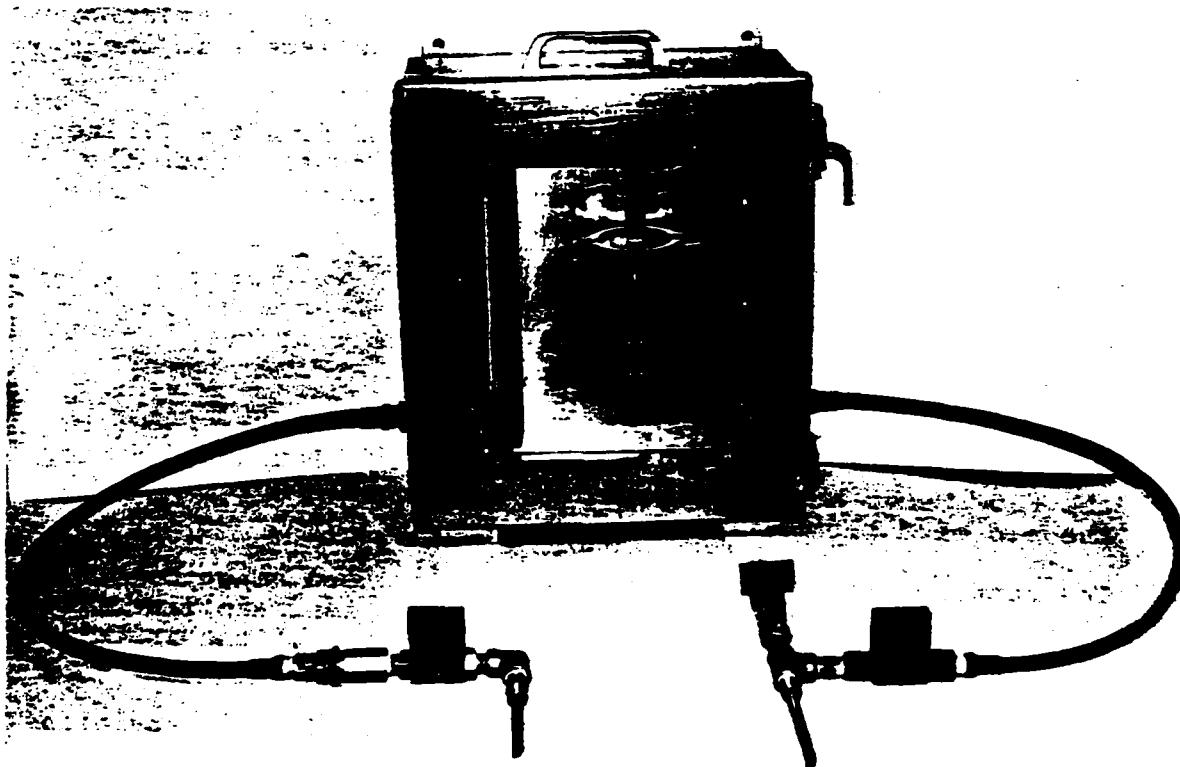
The Flow Meter valve is not to be used for shutting off fuel flow during the testing of the Capsule Holder.

VI. REQUIRED EQUIPMENT AND REFERENCE FUEL

A. Equipment

1. Filter Sidestream Sensor assembly with associated hardware, including probes and stainless steel or aluminum tubing, as illustrated in Figure 2. The tubing and probes are not supplied as part of the Filter Sidestream Sensor assembly because much of the required apparatus may already be installed for sampling purposes. Connecting hardware is available as needed.

FIGURE 2
FILTER SIDESTREAM SENSOR



INLET

OUTLET

2. Micro-Separometer, Two-Speed, MK V, available from Emcee Electronics. The Minisonic Separometer (MSS) may also be used but special connecting apparatus and instructions must be used. Details are available on request.

NOTE: The newest version of the MK V is referred to as MK V Deluxe. This apparatus will perform the test in the same manner, but it is more automatic and requires no gear shifting to change drive speeds. Refer to Attachment B-1.

3. Holder Bracket (GTP-3242) to support the Capsule Holder on the Micro-Separometer.
4. Tubing Assembly (GTP-3254) to connect the syringe on the Micro-Separometer to the inlet of the Capsule Holder.
5. Micropipette, Wire Aid and six packs of disposable glass vials. This apparatus consists of disposable equipment required for the operation of the Micro-Separometer.

B. Reference Fuel

One gallon or four liters of Reference Fuel, verified by the Micro-Separometer test to have a 98-100 MSEP rating. The Reference Fuel may be taken from the local Jet A or A-1 fuel system and may contain additives, provided it meets the 98-100 MSEP rating requirement. This quantity of fuel should provide sufficient supply for several months of testing.

If no local supply of 98-100 MSEP Reference Fuel can be obtained, a 100 MSEP Reference Fuel can be prepared from the local Jet A or A-1 fuel system by clay treatment, using Claycel purchased from Emcee Electronics (Part No. 840-99-5946).

The fuel should be stored in an approved epoxy-lined one-gallon or four-liter sample can meeting ASTM D-4306-84 sample container requirements. Mark the can to identify the fuel.

CAUTION: This Reference Fuel that is used in Filter Sidestream Sensor ratings must not be confused with the Reference Fuel that is used in Clay Sidestream Sensor applications. A special additive concentrate is used in the Clay Reference Fuel.

VII. OPERATING PROCEDURESA. New Capsule Installation, Pre-conditioning and Flow Regulation1.0 Installation

A new Capsule is installed in the holder and then into the Cabinet affixed to the filter/separator vessel only when new elements are installed in the filter/separator vessel.

A display of Capsule Holder components is shown in Figure 3. A step-wise procedure for assembling a Capsule in the Holder is provided in Figures 4 - 8.

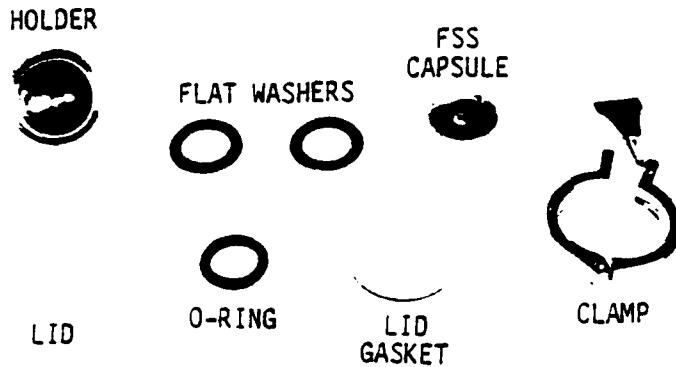


FIGURE 3 - Capsule Holder components.

FIGURE 4 - Place flat washer in the bottom of the Holder.



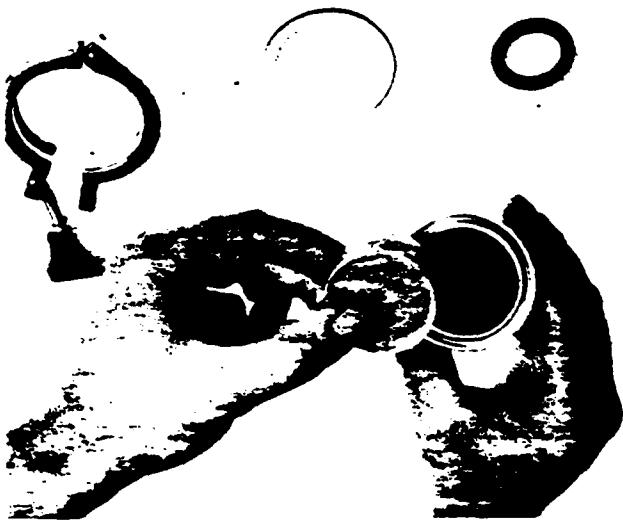


FIGURE 5 - Insert proper Capsule in Holder with crimped edge facing up.

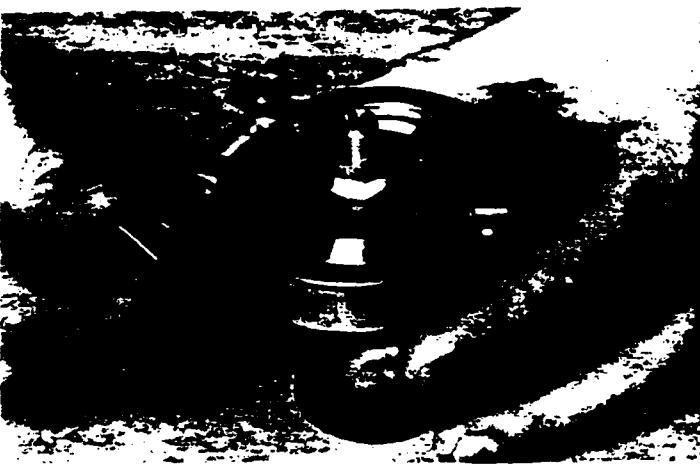
NOTE: Capsule must be the same model as the coalescer elements installed in filter/separator vessel.

FIGURE 6 - Place O-Ring on top of Capsule. O-Ring must fit inside edge rim.



FIGURE 7 - Install Holder lid-gasket and then the lid. Use of a standard vice will simplify the compressing of gaskets, positioning of lid to the Holder body and installing the lid clamp (see next step).

FIGURE 8 - Install clamp and tighten as firmly as possible.



2.0 Pre-conditioning

After the new Capsule is installed in the Capsule Holder, the Capsule must be pre-conditioned and tested to ensure that flow is not by-passing the Capsule internally. The procedure given below utilizes the two-speed Mark V Micro-Separometer instrument. (If an MSS is to be used instead of the Micro-Separometer, detailed instructions are available on request. Also, refer to ASTM Method D3602.)

For further details on description and operation of the Micro-Separometer, refer to instructions provided with the instrument. For detailed test procedures, refer to ASTM Standard Method D-3948.

Following is a step-wise procedure for testing the Capsule Holder assembly:

2.1 Change the syringe drive gear selector in the Micro-Separometer instrument to HIGH by lifting the release knob located on the top left of the syringe drive casting. The movable gear carriage located on the lower right-hand side of the housing can then be pushed to the left, as shown in Figure 9. While holding the gear carriage in, lower the release knob to lock it in place. See Attachment B-I if a MK UV Deluxe is used.

2.2 Turn power switch to ON.

2.3 Preset UP/AUTO/DOWN switch to AUTO.

2.4 Preset MODE switch to A (the green light above the drive switch should illuminate).

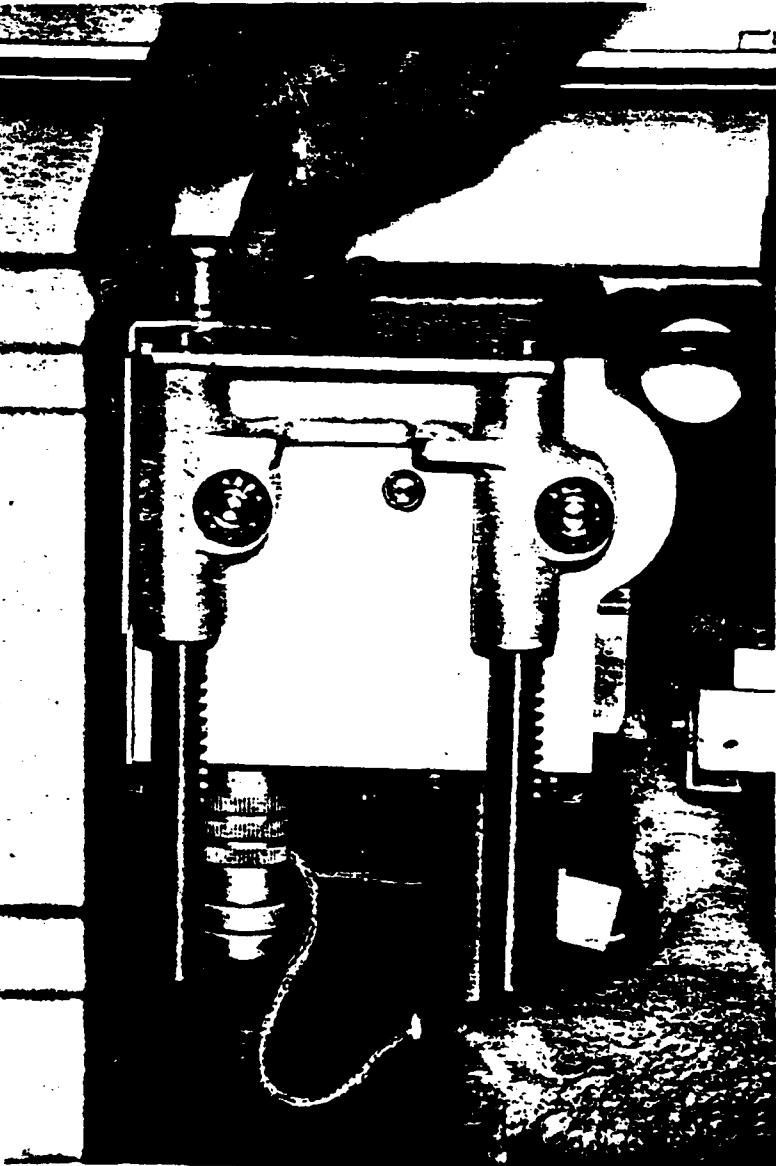
NOTE: With the MODE switch in the "A" position and the syringe drive in "HIGH", the syringe drive time duration is 15 seconds.

2.5 Remove plunger from the plastic syringe and pour 50 milliliters of Reference Fuel into the barrel.

- 2.6 Inject 10,000 ppm of free water by introducing ten 50-microliter injections with Micropipette, provided with Micro-Separometer.
- 2.7 Attach the syringe barrel to the Emulsifier Bracket.
- 2.8 Depress DRIVE switch to emulsify the fuel/water mixture. After approximately 3 seconds delay, the Emulsifier will turn on and remain on for 30 seconds. During this time, the syringe drive will move to the upper position and stop.
- 2.9 Insert the Holder Bracket on the Micro-Separometer in the slot above the stirrer (see Figure 10).
- 2.10 Place the Capsule Holder in Bracket and connect the tubing from the Holder top to the syringe.
- 2.11 Insert plunger in the syringe.

FIGURE 9 - Syringe Drive Gear Selector. Gear carriage is at lower right under thumb. Release knob is at upper left.

NOTE: When using the MK V Deluxe version of the Micro-Separometer, there is no need to make gear changes. See Attachment B-1.



B-10

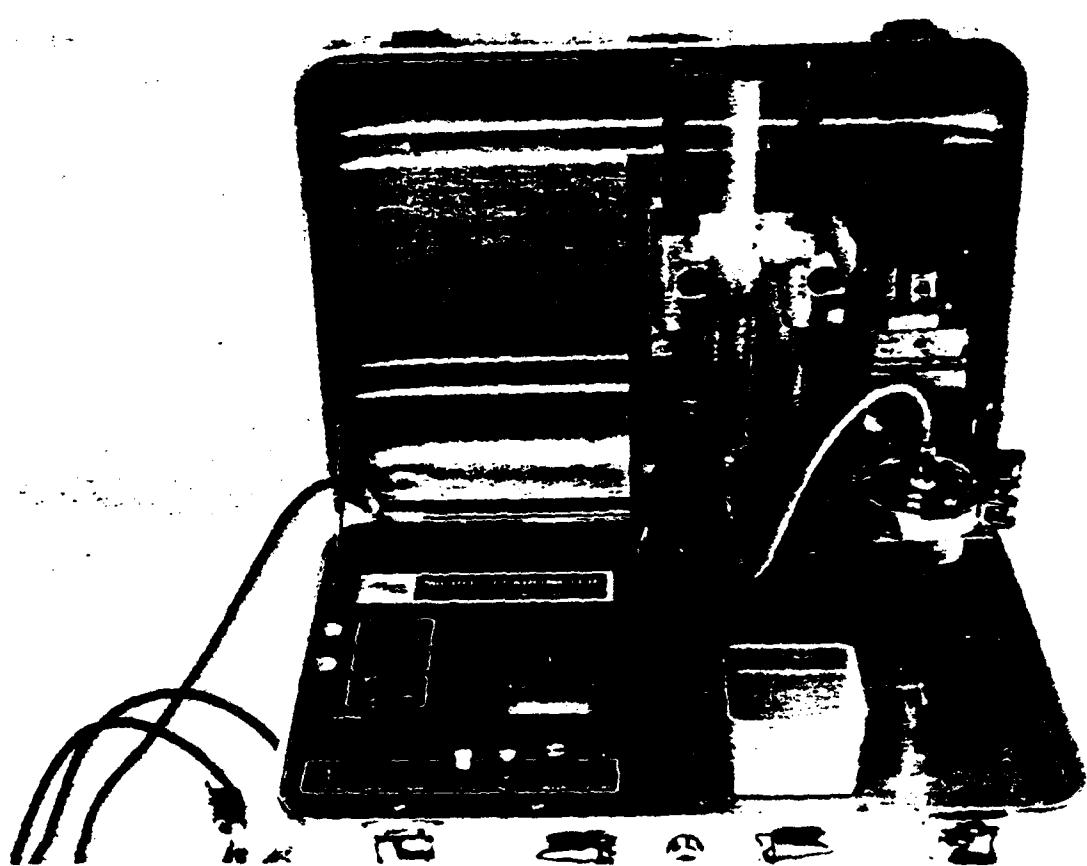


FIGURE 10

2.12 Depress DRIVE switch. This will start an automatic program consisting of the following sequential actions:

<u>Action</u>	<u>Duration, Sec.</u>	<u>Operation</u>
Pulse Audible Tone	4	-
Meter Adjust Period (As described in the Micro-Separometer instructions, the meter adjustment is made with a clean glass vial containing clean reference fuel, with no emulsified water present.)	10	Adjust the Meter control knob to read 100. Dispose of the fuel that is collected in the glass vial during the Meter Adjust Period.
Syringe Drive Down	15	Collect the last 15 ml. of the effluent fuel into same glass vial.
Steady Audible Tone	4	Place the vial into the turbidimeter.
Meter Read #1	10	Take the first turbidity reading.
Wait	46	-
Steady Audible Tone	4	-
Meter Read #2	10	Take the second turbidity reading.

Upon completion of the automatic Capsule testing program, the instrument will automatically reset.

2.13 If the measured turbidity in the Micro-Separometer is 96 or less, the flow is by-passing the Capsule or it may be defective. The Capsule Holder should be dismantled and gaskets checked to ensure that proper gaskets have been correctly installed. The Capsule Holder should then be re-assembled and re-tested.

2.14 If a low reading is again obtained, the Capsule may be defective and a new one should be installed and tested. Turbidity reading of at least 97 must be obtained before the Capsule Holder assembly can be installed in the Cabinet for operation.

3.0 Initial Capsule Testing

3.1 After a new Capsule is installed in the Holder and has been pre-conditioned, repeat all steps in 2.1 through 2.12 with 3,000 ppm of free water injected into 50 milliliters of Reference Fuel in Step 2.6 (three Micro pipette injections).

Repeat again all steps in 2.1 through 2.12 with 1,000 ppm of free water injected into 50 milliliters of Reference Fuel in step 2.6 (one Micropipette injection). This will establish a base rating for the new Capsule.

3.2 Record results obtained in Step 2.12 for "zero" throughput in the suggested data sheet. See Table 1, attached.

4.0 Flow Regulation

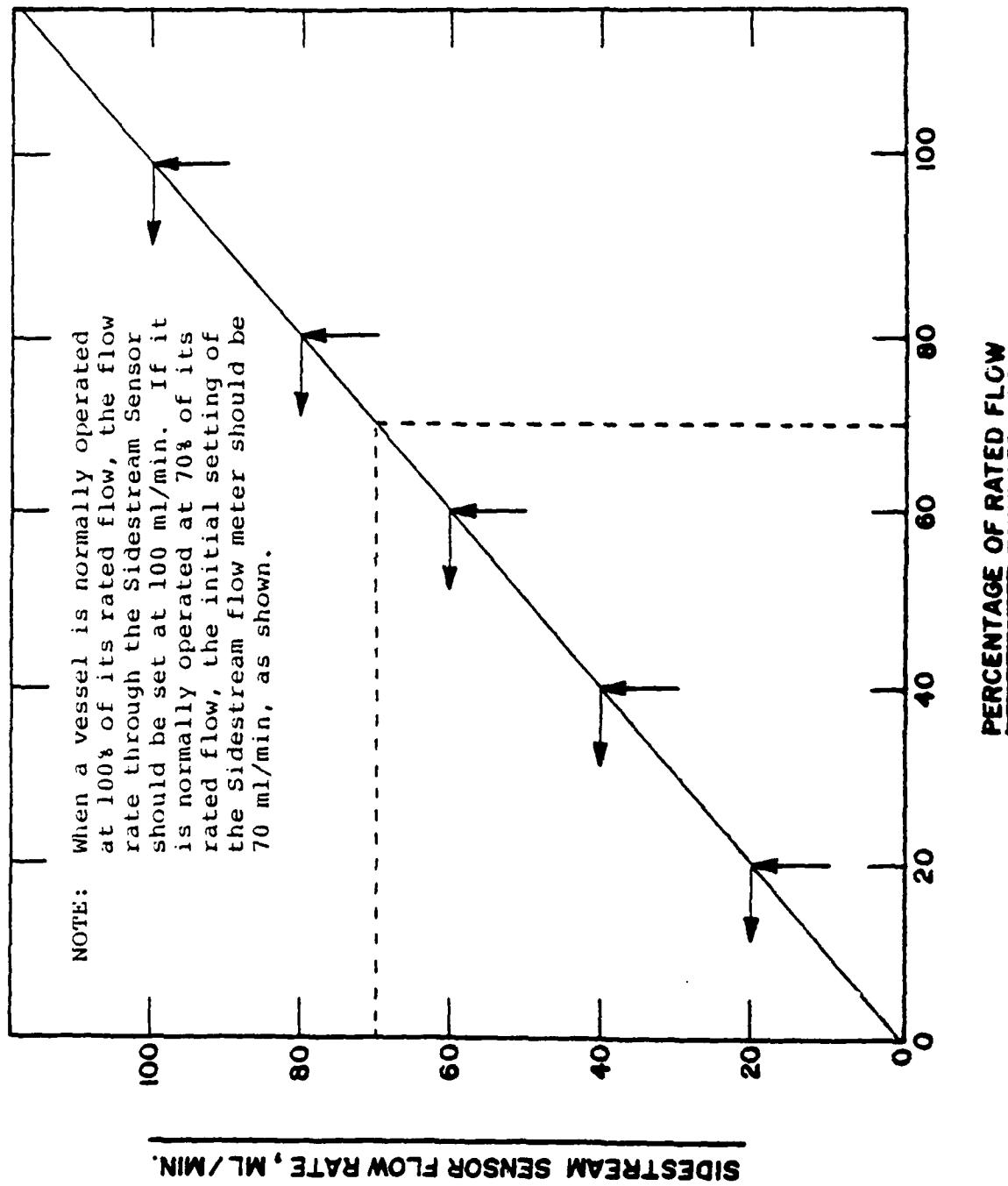
4.1 After the Capsule Holder has been installed in the Cabinet, bleed air from the tubing through the vent valve near the top of the Cabinet.

4.2 Set fuel flow with the Flow Meter to give a flow rate of 100 milliliters per minute through the Capsule while the filter/sePARATOR unit is operating at rated flow.

4.3 If the filter/sePARATOR unit normally operates at lower than rated flow, see Figure 11 and adjust the Flow Meter at a lower flow rate, as explained in the example. Be sure that the filter separator is operating at its normal flow rate when setting the side stream flow rate through the Capsule.

4.4 Check and record the Capsule and filter/sePARATOR flow rates weekly to ensure that flow relationship between the Capsule and the filter/sePARATOR unit, established initially, is being maintained. Re-adjust, if necessary.

FIGURE 11
FILTER SIDESTREAM SENSOR FLOW CALIBRATION



B. Periodic Capsule Testing and Evaluation of Results

1.0 Testing

The Capsule Holder is removed from the Cabinet and is tested in the assembled condition in the Micro-Separometer. It can be removed for testing at any time, regardless of whether the filter/separator unit is in operation. Suggested testing time interval as a function of estimated coalescer life is as follows:

<u>Estimated Coalescer Life (Historical Element Change-out)</u>	<u>Capsule Testing Interval</u>
3 - 6 Months	Every two weeks
6 -18 Months	Once a month
Longer than 18 months	Every two months

Twice as frequent Capsule testing as that suggested above is recommended when higher than normal levels of surfactants, indicated by low fuel MSEP ratings, are known to be present in the incoming fuel.

Two tests are required to be carried out with the operating Capsule at each testing interval. The first is run with 3,000 ppm of water added to the Reference Fuel. The second run is made with 1,000 ppm of water. Except for the different levels of added water to the Reference Fuel, both tests are identical in all other respects. Total testing time is estimated to be 10-15 minutes.

2.0 First Test of Capsule

- 2.1 Remove Capsule Holder by closing both valves on the inlet and outlet sampling probe lines.

Do not close the Flow Meter valve.
- 2.2 Remove the Capsule Holder from the Cabinet by loosening the tubing fittings on the top and bottom of the Holder.
- 2.3 Repeat all Steps in A2.1 through A2.12 except inject 3,000 ppm of free water (three Micropipette injections) into 50 milliliters of Reference Fuel in Step A2.6.
- 2.4 Record results obtained in Step A2.12 in the suggested data sheet.

3.0 Second Test of Capsule

- 3.1 Repeat all tests in Step 2.3 above, except inject 1,000 ppm of free water (one Micropipette injection) into 50 milliliters of Reference Fuel in Step A2.6.

3.2 Record results.

3.3 Plot a graph of filter/separator throughput or time as a function of the lowest individual reading obtained on the Capsule to determine a trend in the performance of the filter/separator. See Attachment B-II for a discussion.

3.4 If the 15 ml sample is missed, spilled or a reading is missed, do not repeat either Steps 2.0 or 3.0 at this time. Wait until the next test interval.

4.0 Evaluation of Results

4.1 When all four readings in the above two tests are greater than 85, the coalescer elements in the filter/separator vessel are considered to be in good condition. The Capsule Holder is placed back in operation until the next testing interval.

4.2 A single reading of 85 or less indicates that coalescer elements in the filter/separator unit have become deactivated. The coalescer elements must be changed immediately and a new Capsule is to be installed in the Holder and tested in accordance with the procedure provided under "New Capsule Pre-conditioning".

4.3 If an individual reading is between 85 and 90, deactivation of the coalescer elements may occur soon and testing frequency should be increased to about three times as often as originally scheduled.

5.0 Returning Capsule Holder Back into Operation

5.1 Remove the syringe adapter from the Capsule Holder and install it in the Cabinet. Tighten the tubing fittings to prevent leaks.

5.2 Open the valves on the sampling probes.

5.3 Bleed air from the tubing through the vent valve.

5.4 Check the flow setting on the Flow Meter against the filter/separator flow. Adjust according to the Calibration Curve provided in Figure 11.

VIII. MAINTENANCE AND REPLACEMENT PARTS

A. Maintenance of Equipment

1. Filter Sidestream Sensor

Little, if any, maintenance should be required of the Filter Sidestream Sensor. Should breakage of the Flow Meter, valves, tubing or probes occur, replacement parts should be ordered from:

Gammon Technical Products, Inc.
235 Parker Avenue
P. O. Box 400
Manasquan, New Jersey 08736-0400

Tel. (201) 223-4600

Cable Address: Gammotech-Manasquan

Telex: 132484 Gammontec - MNQN

2. Micro-Separameter

Repairs and support equipment for the Micro-Separameter should be ordered from:

Emcse Electronics
8875 Midnight Pass Road
Sarasota, Florida 33581
U.S.A.

Tel: (813) 349-6000

TWX: 810-864-0405

B. Replacement of Parts

1. New Capsules, gaskets to stack on top of and under the Capsule, and Capsule Holder lid gaskets should be ordered from Gammon Technical Products, Inc.
2. When ordering replacement Capsules, state the make, model and API Group Classification (A, B or C) of the coalescers which will be installed in the filter/separator vessel. It is absolutely essential to have the Capsule matched with the coalescer elements in the filter/separator vessel whose performance is being monitored by the Sidestream Sensor.
3. Stacking gaskets for the Capsule should last indefinitely; additional supplies can be ordered, if necessary.

TABLE 1
DATA LOG
FILTRATION SIDESTREAM SENSOR FOR FILTER SEPARATORS

ATTACHMENT B-I
MICRO-SEPAROMETER
MARK V DELUXE

- 1.0 The Micro-Separometer, Mark V Deluxe can be used for the Filter Sidestream Capsule evaluation using the following procedure to replace Steps 2.2 through 2.12 on pages B-8 through B-11.
- 1.1 Momentarily depress the "ON" switch. The annunciation lamps located on the switches A through G in the switch array will commence scanning.
- 1.2 Depress switch "E" to initiate the standard automatic program. Scanning will cease and switch "E" will stay illuminated. The annunciator lamp on the START switch will illuminate indicating that the program can be initiated.
- 1.3 Remove plunger from the plastic syringe and pour 50 milliliters of Reference Fuel into the barrel.
- 1.4 Inject 10,000 ppm of free water into the fuel using the 50 microliter pipette. A total of ten injections will be required.
- 1.5 Attach the syringe barrel to the Emulsifier Bracket.
- 1.6 Momentarily depress the START switch. The Emulsifier will activate for 30 seconds and the Syringe Drive Mechanism will rise to the "UP" position.
- 1.7 At the conclusion of the emulsification cycle, insert the Holder Bracket on the Micro-Separometer in the slot above the stirrer.
- 1.8 Place the Capsule Holder in the Bracket and connect the tubing from the Holder top to the syringe.
- 1.9 Remove the syringe from the emulsifier and insert the plunger using the Wire Aid.
- 1.10 Remove the plug from the bottom of the syringe barrel and affix the F/S Monitor Filter.
- 1.11 Momentarily depress the START switch. This will initiate the Automatic Program as shown in paragraph 2.12 on page B-11.
- 1.12 Upon completion of the Program, the instrument will automatically reset thus allowing the selection of another test.

ATTACHMENT B-II

TESTING THE FILTER SIDESTREAM SENSOR

The Capsule testing procedure requires that the first test use 98 to 100 MSEP Reference Fuel containing 3,000 ppm of free water and that a second test follow with Reference Fuel containing 1,000 ppm of free water. After each test, the turbidity of the last 15 ml of effluent is measured in the Micro-Separometer immediately and after one minute.

The reasons for the double test technique relate to the general mechanism of coalescence and deactivation. In order to cause deactivation, both water and surfactant must be present. In order to test for deactivation, water must also be present. The first test with 3,000 ppm of free water is to insure that the components within the capsule are completely wetted. Should the Capsule be dry because there was no water in the main fuel system, most of 3,000 ppm water may be absorbed, and very little would emerge to be tested for turbidity in the Micro-Separometer. In this case, the second test with 1,000 ppm of free water would represent the real test of the coalescence efficiency of the Capsule.

If surfactant has affected the coalescing efficiency of the Capsule, the turbidity readings of the last increment of effluent will indicate this, because the emerging water droplets will be fine and dispersed and, therefore, scatter light. By letting the sample settle quietly for one minute, the largest water droplets will be removed and a second turbidity reading will indicate only the fine water droplets that remain in suspension.

How would results be interpreted? These examples will illustrate the appropriate interpretation.

READINGS* 1st TEST	READINGS* 2nd TEST	INTERPRETATION
100/100	85/85	Capsule was dry, but second test revealed deactivation.
100/100	100/100	Capsule indicated no deactivation.
90/95	85/85	Capsule was not dry and second test confirmed deactivation.
85/85	85/85	Capsule was not dry and first test confirmed deactivation.

* IMMEDIATE/ONE MINUTE READINGS

The amount of surfactant present in a Capsule that is deactivated may be very small. Some is invariably extracted by the water that is used in the first and second tests. Hence, if either test is spoiled by operator or equipment malfunction, the sensor should be returned to the Filter Sidestream Sensor Cabinet for further operation, rather than be retested with still more water.

A P P E N D I X C

OPERATING MANUAL:
CLAY SIDESTREAM SENSOR
FOR
CLAY TREATMENT VESSELS

CLAY SIDESTREAM SENSOR

FOR

CLAY TREATMENT VESSELS

I. INTRODUCTION

Clay treatment of jet fuel is used to remove a type of contamination called surfactants. These compounds are carried over from refinery processing units or picked up in the distribution system. Very small amounts of these contaminants make it difficult to separate water from fuel. Removal of surfactants from jet fuel is necessary to prevent disarming of downstream filter/separators.

Currently, the performance of clay treating equipment is monitored by the WSIM (ASTM D2550) test or its field equivalents, the Micro-Separometer or Minisonic Separometer (MSS). The efficiency of the clay can be measured by observing the improvement in WSIM as the fuel passes through the elements. However, use of these tests requires that the clay vessel be operating at the time of the test and that entering fuel contain surfactants.

The signal that clay is no longer active usually occurs only after surfactants "break through" the clay and are found in about the same concentration as in the inlet fuel, i.e. no improvement in the WSIM test. Unfortunately, there has been no monitoring technique available to give advanced warning of this impending surfactant breakthrough. Once it occurs, the clay vessel is useless, except possibly for some dirt removal.

A clay monitoring technique has been developed for canister or bag type elements which operates on a side stream flow of the fuel through a Clay Sidestream Sensor. The Sensor has been shown to be an effective tool in monitoring the performance of Clay Treatment Vessels.

II. WHAT IT IS

The Clay Sidestream Sensor is an external device designed to measure and monitor clay performance. It is housed in a small rectangular Cabinet containing the following major components:

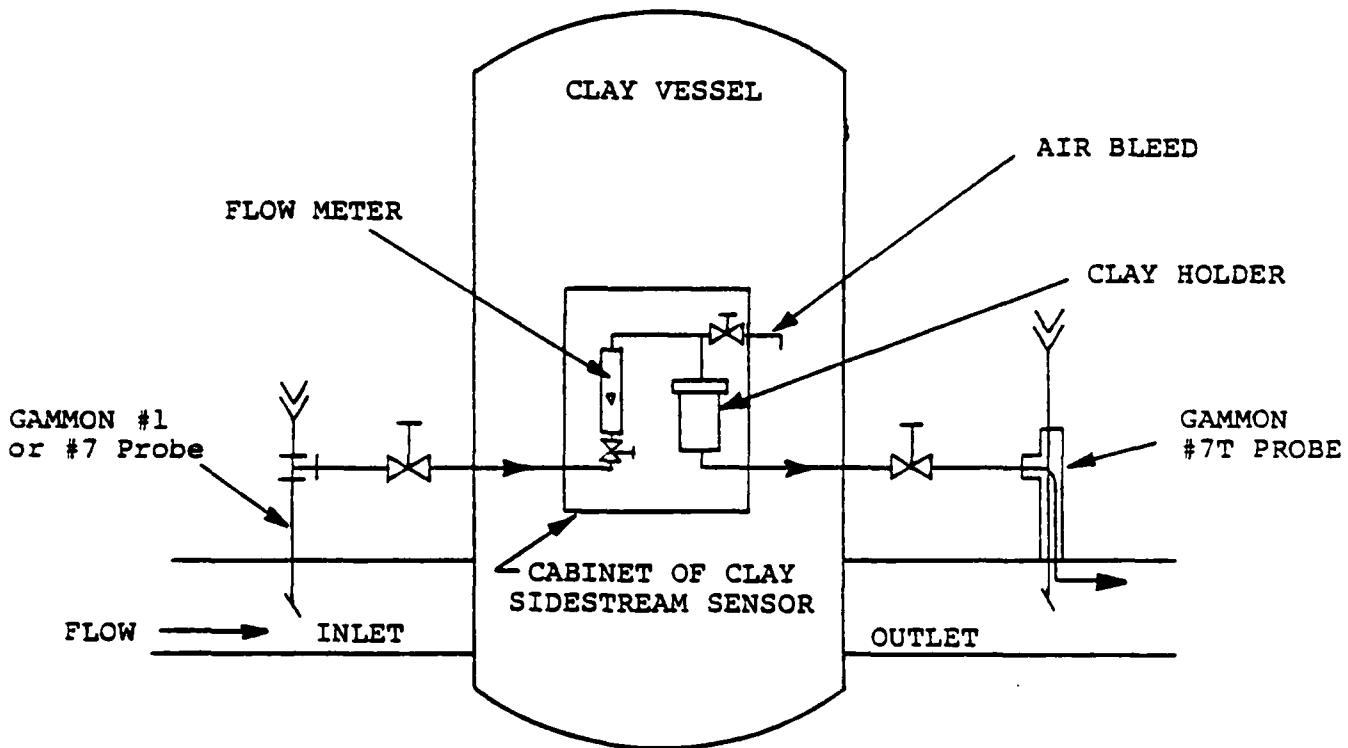
- A Clay Holder which duplicates the clay element construction and flow pattern. It is filled with the same type of clay as the clay vessel.
- A Flow Meter for setting fuel flow rate through the Clay Holder, proportional to the flow rate through the clay in the vessel.

Supplementary equipment, which may already be installed, is also necessary:

- o Sampling probes for insertion in the inlet and outlet connections of the Clay Treatment Vessel.
- o Tubing, valves and fittings for connecting the Sensor Cabinet to the sampling probes. For reasons of fire safety, all connections should be of metal.

A schematic of the complete Sensor assembly attached to the clay vessel, together with tubing and sampling probes, is provided below in Figure 1.

FIGURE 1
SCHEMATIC OF CLAY SIDESTREAM SENSOR INSTALLED ON CLAY VESSEL



NOTE: Probes should extend to near the center of the pipe.

III. WHAT IT DOES

The Clay Sidestream Sensor provides a realistic measure of current clay performance in removing surfactants from the fuel. Filter separators are adversely affected by surfactants and are subject to expensive maintenance. The Clay Sidestream Sensor is used to detect the onset of clay deactivation in the clay vessel that is located upstream of the filter/sePARATOR. Clay elements can now be changed on the basis of actual performance rather than the current basis of indirect measurements that are not related to surfactant removal.

IV. HOW IT WORKS

Fuel enters the Clay Sidestream Sensor through the inlet probe at a rate proportional to the flow through the clay vessel. The Sensor inlet flow rate is set by the valve on the Flow Meter. Once the rate is set, the Flow Meter automatically maintains the flow to the Sensor in proportion to any flow variations in the clay vessel.

The Clay Sidestream Sensor works on the principle of dynamic flow similarity between the Clay Holder and the clay elements in the main vessel. Each section of a clay element is arranged in the Holder to duplicate, in small scale, each component of the clay element in the clay vessel. The clay is changed each time new elements are installed in the clay vessel. Thus, the clay in the Sidestream Sensor is exposed to the same cumulative effects of fuel surfactants as the elements in the clay vessel.

Periodically, the Clay Holder is removed from the Cabinet and tested with a reference fuel for its ability to remove surfactants. Details of the test procedure are provided under section entitled "Operating Procedures".

V. WHERE AND HOW INSTALLED

The Cabinet should be firmly attached with brackets to the clay vessel body or at a convenient location near it so that the sampling lines are as short as possible. It should be mounted at eye level to permit easy reading of the Flow Meter. For maximum accuracy, the Flow Meter must be mounted in a vertical position (with the aid of a plumb).

The sampling probes, if not already installed, must be extended through the pipe wall, well into the main line flow. Refer to Figure 1 which provides a schematic of the installation.

Fuel sampling tubing should be of metal (preferably stainless steel) and installed so that it will not be damaged during maintenance operations.

A shut-off valve should be installed in both the inlet and the outlet line - between the Sensor and the sampling probes - to shut off fuel during periodic removal and testing of the Clay Holder. These valves should be installed as part of the sample probe assembly.

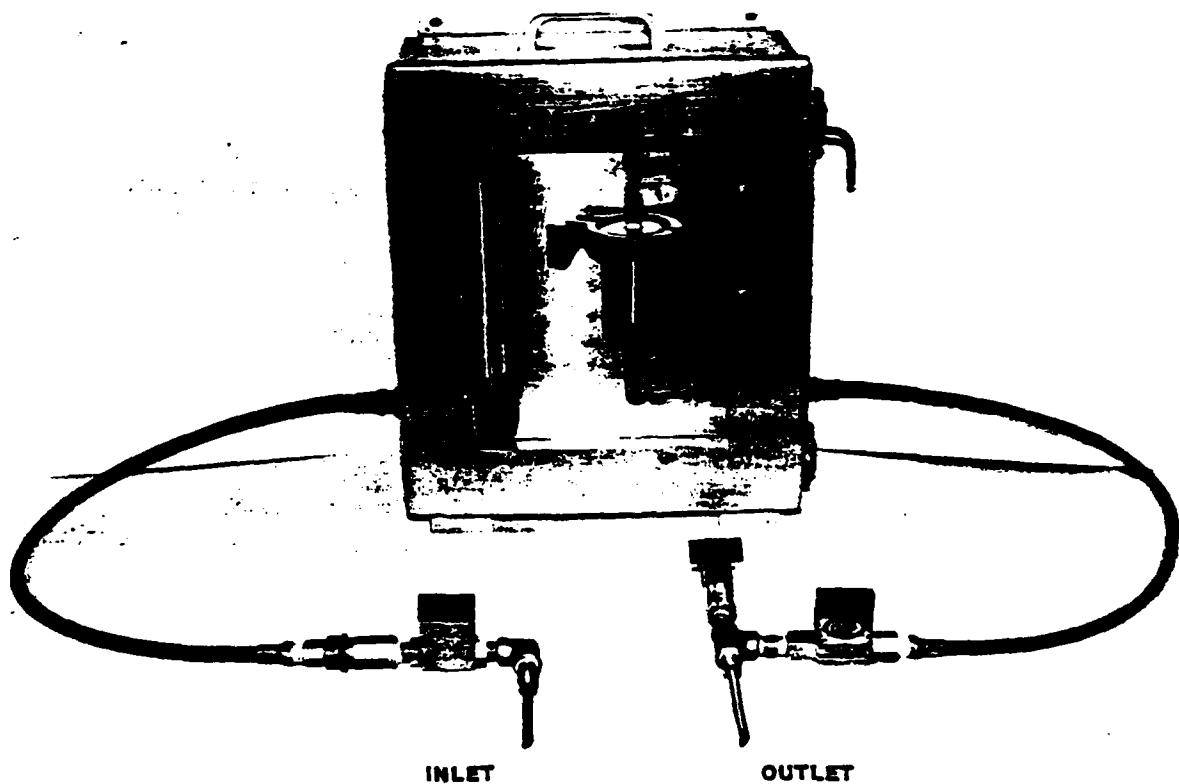
The Flow Meter valve is not to be used for shutting off fuel flow during the testing of the Clay Holder.

VI. REQUIRED EQUIPMENT AND REFERENCE FUEL

A. Equipment

1. Clay Sidestream Sensor assembly with associated hardware including probes and stainless steel or aluminum tubing as illustrated in Figure 2. The tubing and probes are not supplied as part of the Sidestream Sensor assembly because much of the apparatus may already be installed for sampling purposes. Connecting hardware is available as needed.

FIGURE 2
CLAY SIDESTREAM SENSOR



2. Micro-Separometer, Two-Speed, MK V, available from Emcee Electronics. If a MK V Deluxe is used, refer to Attachment C-1. The Minisonic Separometer (MSS) may be used with special connecting apparatus. Instructions are available on request.
3. Holder Bracket (GTP-3242), to support the Clay Holder on the Micro-Separometer.
4. Tubing Assembly (GTP-3254), to connect the syringe on the Micro-Separometer to the inlet of the Clay Holder.
5. Micropipette, Wire Aid and six-packs of disposable glass vials. This apparatus consists of disposable equipment required for the operation of the Micro-Separometer.
6. Three special 50-milliliter flasks, available from Gammon Technical Products, for collecting effluent fuel from the Clay Holder.

B. Reference Fuel

One gallon or four liters of Reference Fuel is prepared from a local fuel supply system to which Reference Additive Concentrate is added (available from Gammon Technical Products). This quantity of fuel should provide sufficient supply for several months of Sensor testing.

CAUTION: Care must be taken to clearly label the Clay Reference Fuel containers so that they will not be confused with the Reference Fuel that is used in Filter Sidestream Sensor tests where no Additive Concentrate is used.

1. Take a sample of Jet A or A-1 fuel downstream of an operating clay vessel into a one-gallon or four-liter epoxy-lined can meeting ASTM D-4306-84 sample container requirements.
2. Add the entire contents of the Reference Additive Concentrate bottle.
3. Cap and shake the can for 5 - 10 seconds to completely disperse the additive in the fuel.
4. Properly identify the can as the "Clay Sidestream Reference Fuel containing Reference Additive".
5. Run a WSIM test in a Micro-Separometer. A WSIM rating of approximately 40 to 60 is expected.
6. Record the WSIM rating on the container and on the suggested data sheet provided in attached Table 1.

VII. OPERATING PROCEDURESA. New Clay Holder Installation, Pre-conditioning and Flow Regulation1.0 Installation

A Clay Holder with new clay is installed in the Cabinet only when new elements are installed in the clay vessel.

A display of Clay Holder components is shown in Figure 3. A step-wise procedure for assembling the Clay Holder is provided in Figures 4 - 10.

Figure 3 - Clay Holder components including precut sections from clay element (bag or canister type). The technician is expected to cut these parts from a new element and save the clay in a tight jar for use in the Clay Holder.



Figure 4 - Insert components in the order shown:

- A Gasket
- B Steel screen, cut from element center tube.
- C Gasket
- D Paper (one or two-ply as constructed in element).

NOTE: Do not use the extra paper from the top 3 - 4 inches of an element, as this paper is wrapped around the center tube to prevent flow by-pass over the top of the clay as the clay settles during use.

Figure 5 - Insert cone spacer (E) (large end of cone in top) and pour clay (F) into cavity.



Figure 6 - Tap sides of Holder to settle clay and fill in voids. Add make-up clay as required to bring level to top of the cone section.

Figure 7 - Place section of paper/fabric (G) from outside of element on top of clay and cone.



Figure 8 - Insert one or two Teflon rings (H) on top of paper/fabric section.



Figure 9 - Insert gasket ring (J) and gasket (K) as required to give firm compression of all components when top is clamped in place. Sufficient gaskets should be used to allow a 1/16 to 1/8 inch compression of gaskets when lid is clamped in place.



Figure 10 - Install Holder lid-gasket (L), lid (M) and clamp (N). Use of a bench vise will aid in compressing gaskets, positioning the lid to Holder body and installing the lid clamp. Tighten clamp as firmly as possible.

2.0 Pre-Conditioning

Following installation of clay element components in the Clay Holder, it must be tested to ensure that flow will not by-pass the clay or the components. The test procedure given below uses the two-speed Mark V Micro-Separometer instrument.

For detailed description and operation of this instrument, refer to instructions provided with the instrument. For the Micro-Separometer test procedure, refer to ASTM Standard Method D-3948. A step-by-step procedure for testing the Clay Holder follows. Total testing time is estimated to be 15 minutes.

- 2.1 Change the syringe drive gear selector in the Micro-Separometer instrument to HIGH by lifting the release knob located on the top left of the syringe drive casting. The movable gear carriage located on the lower right-hand side of the housing can then be pushed to the left as shown in Figure 11. While holding the gear carriage in, lower the release knob to lock it in place. See Attachment C-1 if a MK V Deluxe is used.
- 2.2 Turn power switch to ON.
- 2.3 Preset UP/AUTO/DOWN switch to the UP position. The syringe drive will immediately start up and stop at the top limit. Leave the switch in the UP position.
- 2.4 Remove plunger from the plastic syringe and pour 50 milliliters of Reference Fuel into the syringe barrel.
- 2.5 Replace plunger.
- 2.6 Insert the Holder Bracket on the Micro-Separometer in the slot above the stirrer (see Figure 12).
- 2.7 Place the Clay Holder in Bracket and connect the tubing from the Holder top to the syringe (see Figure 13).
- 2.8 Move UP/AUTO/DOWN switch to the DOWN position. The syringe will immediately start down and will take approximately 15 seconds to complete the drive.
- 2.9 Collect the effluent fuel from the Clay Holder and discard.
- 2.10 Immediately repeat steps 2.3 through 2.9 passing through the Sensor two additional 50-milliliter samples of Reference Fuel in rapid succession.
- 2.11 Collect the entire effluent fuel from each pass in 2.10 separately into 50 ml flasks marked "1" and "2".

NOTE: Occasionally, somewhat less than 50 milliliters of fuel will be collected from the Holder effluent because of a minor hold-up of fuel in the Holder. Collect as much as possible and proceed to step 2.12. Do not add Reference Fuel to flask to bring it up to 50 milliliters.

- 2.12 Reset the UP/AUTO/DOWN switch to the AUTO position and the syringe drive to the NORMAL gear ratio. The instrument is now ready for the standard MSEP test.

Figure 11 - Syringe Drive Gear Selector. Gear carriage is at lower right under thumb. Release knob is at upper left.

NOTE: When using the MK V Deluxe version of the Micro-Separometer, there is no need to make gear changes. See Attachment C-I.

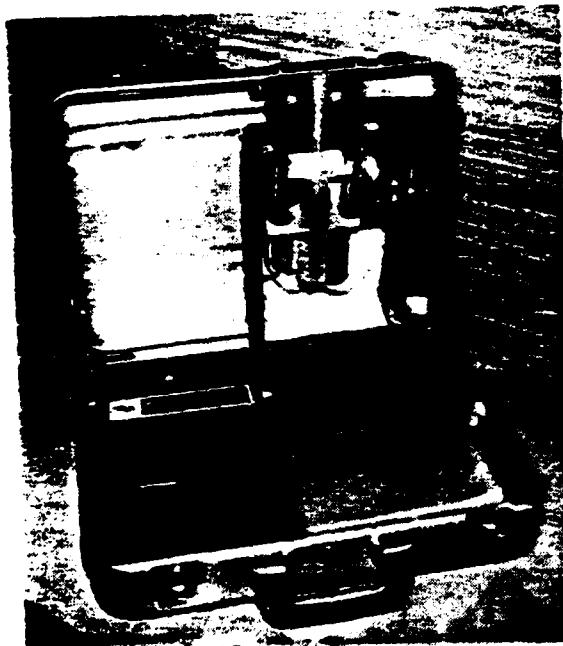
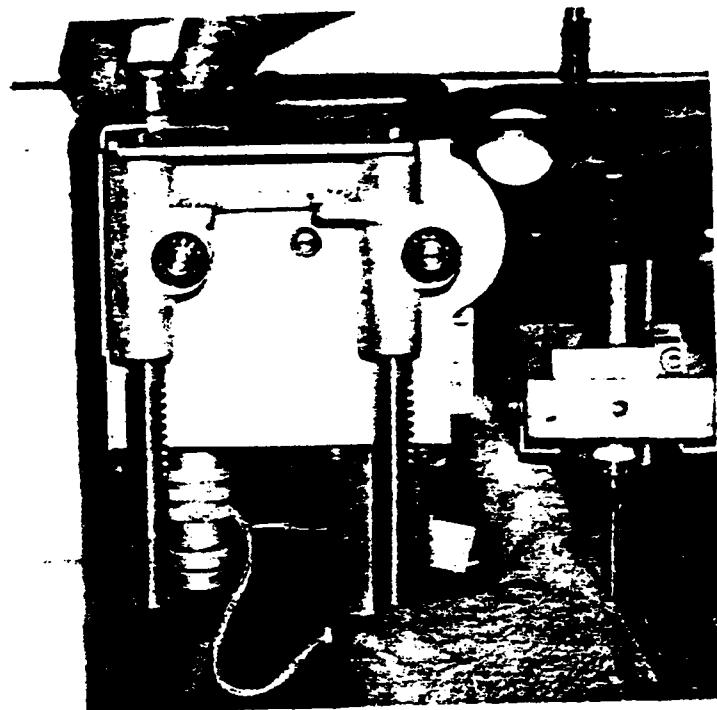
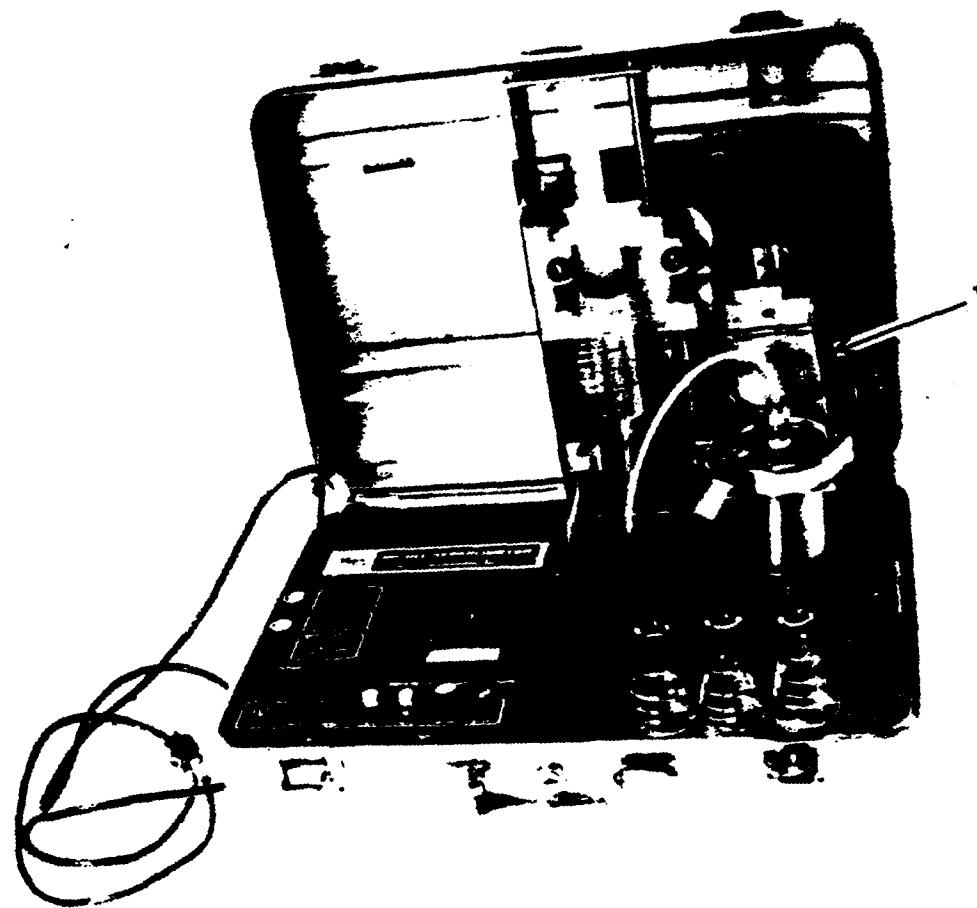


Figure 12 - Holder Bracket in slot above stirrer. Note that this photograph is of the newer Mark V Deluxe Micro-Separometer. The bracket fits in the same way but there is no gear change mechanism because the drive is pre-programmed for the correct drive speed.

C-12

FIGURE 13
MICRO-SEPAROMETER MARK V
WITH CLAY SIDESTREAM SENSOR HOLDER BRACKET



(1) HOLDER BRACKET

- 2.13 Run a standard MSEP test on each of the two samples collected.
- 2.14 Record results in the suggested data sheet provided in the attached Table 1.
- 2.15 If either of the two MSEP runs is less than 96, the flow through the Clay Holder may be by-passing the clay. The Holder should be dismantled, additional clay and/or gaskets installed, and the Holder re-assembled and re-tested.

A MSEP reading of at least 97 must be obtained before the Clay Holder can be installed in the Cabinet for operation.

3.0 Flow Regulation

- 3.1 After the Clay Holder has been installed in the Cabinet, bleed air from the tubing through the vent valve near the top of the Cabinet.
- 3.2 Set the fuel flow rate through the Clay Holder with the aid of the Flow Meter using Figure 14 to determine the rate required in milliliters per minute. The clay vessel must be operating at its normal flow rate when the Flow Meter is adjusted.

NOTE: Normal flow rate is the maximum rate in gpm that will occur in the system. This may or may not be the rated flow of the clay vessel.

- 3.3 Check and record the Clay Holder and clay vessel flow rates weekly to ensure that the flow relationship between the Clay Holder and the clay vessel, established initially, is being maintained. Re-adjust, if necessary.

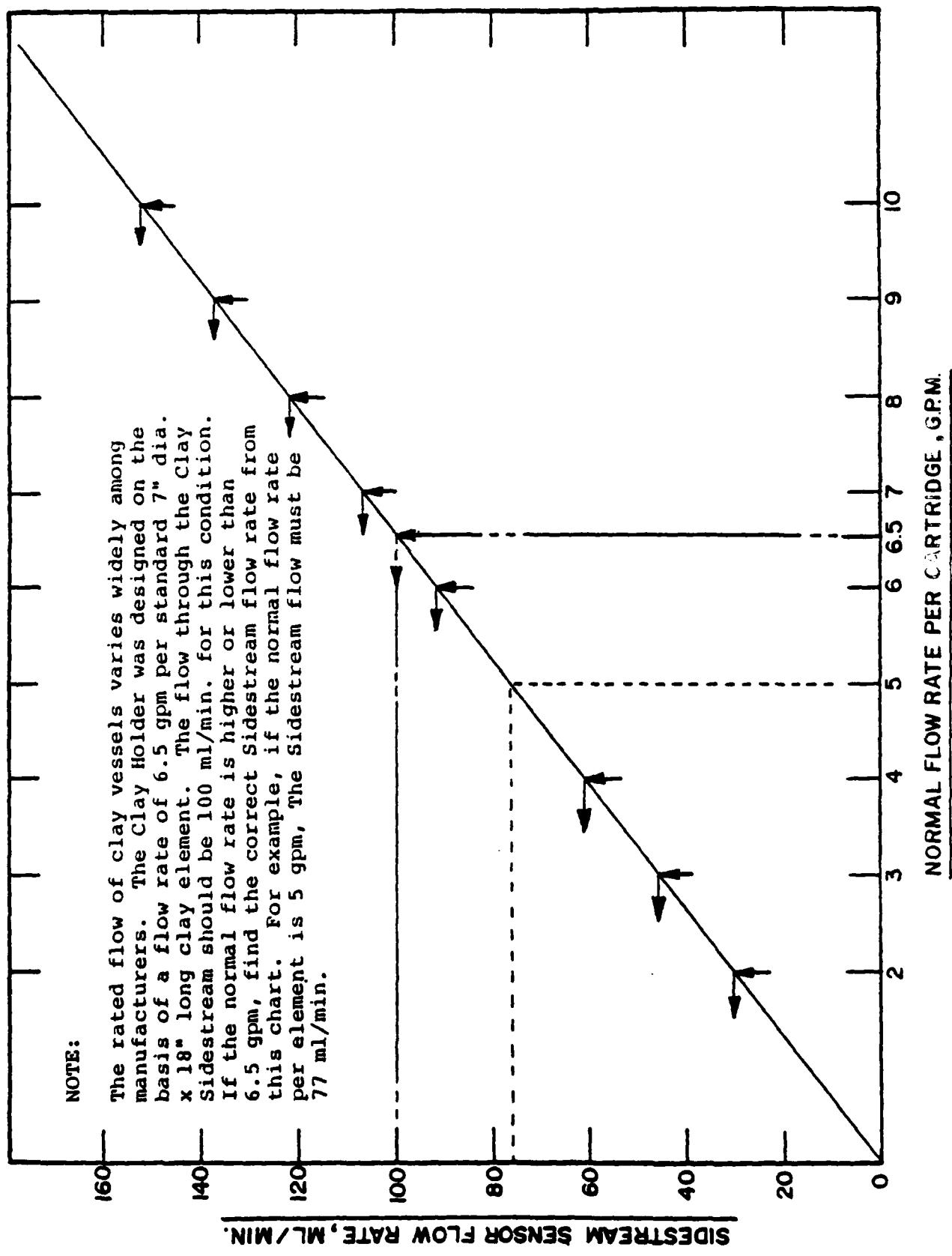
B. Periodic Clay Holder Testing and Evaluation of Results

1.0 Testing

The Clay Holder is removed from the Cabinet and is tested in the assembled condition in the Micro-Separometer. It can be removed for testing at any time regardless of whether the clay vessel is in operation. Suggested testing time interval as a function of estimated clay life is as follows:

<u>Estimated Clay Life</u>	<u>Clay Holder Testing Interval</u>
3 - 6 months	Every two weeks
6 - 18 months	Once a month
Longer than 18 months	Every two months

FIGURE 14
CLAY SIDESTREAM SENSOR FLOW CALIBRATION



Twice as frequent Clay Holder testing as suggested above is recommended when higher than normal levels of surfactants, indicated by fuel MSEPs ratings, are known to be present in the incoming fuel.

Duplicate tests are required to be run with the operating Clay Holder at each testing interval. Total testing time is 10 - 15 minutes.

- 1.1 Shut off flow to Clay Holder by closing both valves on the inlet and outlet sampling probe lines.

Do not close the Flow Meter valve.

- 1.2 Remove the Clay Holder from the Cabinet by loosening the tubing fittings on the top and bottom of the Holder.

- 1.3 Repeat all Steps in A2.1 through A2.8 except prepare two separate 50-milliliter flasks of Reference Fuel in Step A2.4.

- 1.4 Continue testing by following the procedure provided in Step A2.11 through Step A2.14.

- 1.5 Plot a graph of clay vessel cumulative throughput or time as a function of the lowest clay holder rating obtained from the above two tests to determine a trend in the performance of clay in the main vessel.

2.0 Evaluation of Results

- 2.1 If both readings obtained from the above two tests are greater than 93, the clay in the vessel is considered to be still active. The Clay Holder is placed back in operation until the next testing interval.

- 2.2 If either reading is 90 or less, this indicates that clay in the vessel has become deactivated. The elements must be changed immediately and a freshly filled Clay Holder is to be installed and tested in accordance with the procedure provided under "New Clay Holder Pre-Conditioning".

- 2.3 If either reading is between 90 and 93, deactivation of clay may occur soon and testing frequently should be increased to about three times as often as originally scheduled.

3.0 Returning Clay Holder Back into Operation

- 3.1 Remove the syringe adapter from the Clay Holder and install it in the Cabinet. Tighten the tubing fittings to prevent leaks.

- 3.2 Open the valves on the sampling probes.
- 3.3 Bleed air from the tubing through the vent valve.
- 3.4 Check the flow setting on the Flow Meter against the clay vessel flow. Adjust according to the calibration curve provided in Figure 14.

VIII. MAINTENANCE AND REPLACEMENT PARTS

A. Maintenance of Equipment

1. Clay Sidestream Sensor

Little, if any, maintenance should be required of the Sidestream Sensor. Should breakage of the Flow Meter valves, tubing or probes occur, replacement parts should be ordered from:

Gammon Technical Products, Inc.
235 Parker Avenue
P. O. Box 400
Manasquan, New Jersey 08736-0400
U.S.A.

Tel (201) 223-4600

Cable Address: Gammotech - Manasquan

Telex: 132484 Gammontec MNQN

2. Micro-Separometer

Repairs and support equipment for the Micro-Separometer should be ordered from:

Emcee Electronics
8875 Midnight Pass Road
Sarasota, Florida 33581
U.S.A.

Tel: (813) 349-6000

TWX: 810-864-0405

B. Replacement of Parts

1. Parts including stacking gaskets for the Clay Holder should last indefinitely, but should additional supplies be required, they should be ordered from Gammon Technical Products.

TABLE 1
DATA LOG

CLAY SIDESTREAM SENSOR

NORMAL VESSEL FLOW RATE	GPM	ML/MIN.
CLAY HOLDER (SIDESTREAM)	FLOW RATE	

ATTACHMENT C-I

MICRO-SEPAROMETER

MARK V DELUXE

- 1.0 The Micro-Separometer, Mark V Deluxe can be used for the Clay Monitor Test. Use the following procedure to replace steps 2.2 through 2.12 on Page C-10.
- 1.1 Momentarily depress the "ON" switch. The annunciator lamps located on the switches A through G in the switch array will commence scanning.
- 1.2 Depress switch "F" to initiate the standard automatic program for Clay Monitor testing. Scanning will cease and switch "F" will stay illuminated. The annunciator lamps in the SYRINGE section will indicate that the manual control for the syringe drive mechanism can be executed.
- 1.3 Depress the "UP" switch and the syringe drive mechanism will move to the upper limit. The annunciator lamp in the PROGRAM section will indicate the turbidimeter can be manually activated.
- 1.4 Remove plunger from the plastic syringe and pour 50 milliliters of Reference Fuel into the syringe barrel.
- 1.5 Replace plunger using the wire aid.
- 1.6 Insert Holder Bracket on the Micro-Separometer in the slot above the stirrer (see Figure 12).
- 1.7 Place the Clay Holder in Bracket and connect the tubing from the Holder top to the syringe (see Figure 13).
- 1.8 Depress DOWN switch. The syringe will immediately start down and will take approximately 15 seconds to complete the downward excursion.
- 1.9 Collect the effluent from the Clay Holder and discard.
- 1.10 Immediately repeat steps 1.2 through 1.9 passing through the Sensor two additional 50-milliliter samples of Reference Fuel in rapid succession.
- 1.11 Collect the entire effluent fuel from each pass in 1.10 separately into two 50 ml flasks marked "1" & "2".

NOTE: Occasionally, somewhat less than 50 ml of fuel will be collected from the Holder effluent because of a minor hold-up of fuel in the Holder. Collect as much as possible and proceed to Step 1.12. Do not add Reference Fuel to flask to bring it up to 50 ml.
- 1.12 At the conclusion of the test, the annunciator lamps will begin to scan thus allowing the selection of another test.
- 1.13 Proceed to Step 2.13 on Page C-13.

